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Geophysics in War

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GEOPHYSICAL SCIENCE, in a broad sense, is concerned not merely with the physical constitution and the dynamics of the solid earth but with the physical phenomena of the oceans and the atmosphere as well. Within the scope of *applied geophysics*, then, are the numerous detection procedures based on the measurement of fields of force in the earth, the water and the air, and those that utilize the transmission of physical energy through these mediums. Therefore, *geophysical exploration* is a natural part of applied geophysics since it is concerned with all problems of mineral detection.

Wartime applications of geophysics fall into two groups: (1) those directly related to military operations; (2) geophysical exploration for the necessary mineral resources. In the first group various methods are applied in the zone of combat for the detection of hostile guns, submarines and aircraft, for the adjustment of friendly artillery, for the location of hostile weapons, and in signaling and navigation. Geophysical foundation tests are useful in the construction of fortifications, in highway, railroad, bridge and tunnel investigations, and in the construction of ordnance and munitions plants. Other uses of geophysics in the first group include applications of meteorology in land, marine and aerial operations, and the location of shipwrecks and practice weapons. In the second group we have applications of geophysical prospecting methods to the location of water and the investigations of irrigation, drainage, flood control and power projects. Fuels are of paramount importance for the conduct of war, and geophysics is rendering substantial assistance in prospecting for deposits of oil, coal and lignite. Various strategic mineral deposits have been surveyed by geophysical methods; examples are bauxite, chromite, manganese, mercury, nickel, tin and tungsten deposits.

The applications of geophysics in war time are thus as numerous as they are diversified in nature. The present discussion will be limited to a brief review of the more important phases.[1]

Beginning with the applications of geophysics in the zone of combat, we find that various methods are available for the location of the enemy's positions; that is, for the location of hostile guns, sappers, submarines, airplanes and so forth. With the exception of high frequency methods for the location of airplanes and ships, the more important geophysical technics rely on the propagation of sound through the air, the water and the ground. Toward the end of the last war, a successful *sound ranging* method was developed for the location of hostile guns. A num-

[1] For a more detailed discussion, see *Geophysics in war*, Colo. School of Mines Quart., vol. 37, no. 1, (Jan. 1942).

ber of microphones were set up behind the front lines and each of them was connected to a recording unit in an oscillograph camera. Thereby, the arrival times of the gun-muzzle waves could be recorded. As shown in Fig. 1(b), these arrival

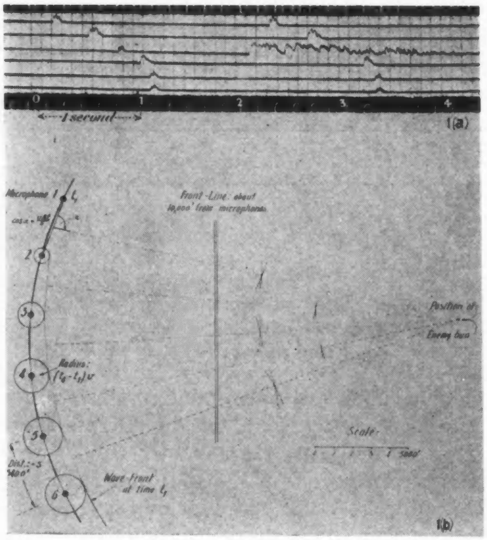

FIG. 1. Sound ranging: (*a*) record, reproduced from the *Encyclopaedia Britannica* (ed. 14), vol. 21, p. 17; (*b*) location of gun from time differences.

times yield the position of the sound wave-front, the gun being in its center. The position of a gun may also be found by sighting on the muzzle-flash from a number of stations; this method is known as *flash ranging*. It is readily seen that flash and sound ranging methods are also applicable to the adjustment of friendly artillery by triangulating shell bursts or smoke puffs. Another acoustic detection method is employed in airplane sound locators and is based on the binaural hearing effect. The locators have two sets of "ears" which may be rotated about a horizontal and a vertical axis into the plane of the wave-front, whereby the horizontal and vertical angles of the sound ray are determined. In trench warfare, a similar method locates enemy sappers, and the sound detectors here used are known as *geophones*. In the earlier stages of the last war, the problem of submarine detection was approached in the same way; that is, by the use of binaural hearing devices with rotatable base. Considerable improvement was later effected by the employment of multiple detectors which were arranged about the hull of a ship and were connected to electric delay networks known as *compensators*. These devices permit of establishing the direction of sound with respect to the ship's axis by rotating a dial which is equipped with a contacting arrangement for connection with the proper delay networks.

Extraordinary demands are made in wartime on communication and navigation at sea. Shore stations are usually cut off, and vessels in motion cannot use their radio communication facilities freely because of the danger of betraying their positions. Hence, acoustic transmission methods, particularly in the ultrasonic range, give better directional discrimination and, in combat, are less vulnerable than radio. Relative to navigation, two methods deserve mention. One is the *RAR method of position finding*, which involves the procedure of determining one's position at sea by measuring the travel time of a sound impulse, initiated by dropping a depth charge, to two points of known coordinates. A hydrophone buoy is anchored at each of these points and radioes the arrival of the sound impulses back to the ship.

During periods of poor visibility, navigation is aided by echo-sounding in waters whose bottom relief has been charted. *Sonic depth finding*, as this echo-sounding method is called, is in many respects similar to the seismic reflection method, well known to the practicing geophysicist. An audio- or high frequency acoustic impulse is initiated on one side of the ship and the echo from the ocean bottom is received on the other side. The time interval between the two is indicated by a rotating dial or is recorded as a continuous sea-bottom profile (Fig. 2). The accuracy of these devices is remarkable. In shallow waters it is possible to detect the presence of objects that project only a few inches from the bottom. Marine echo-sounding methods have their counterpart aboard an airplane in the so-called *terrain clearance indicator*. Using a frequency-modulated radio wave, this device indicates the height of the airplane above the ground by the ingenious means of translating the time delay or phase shift between the original and the reflected wave into variations of frequency.

Because of their accuracy and directional discrimination, high frequency echo-sounding devices are well suited to the location of shipwrecks in salvage operations. Figure 2 is a sonic-depth record off the coast of southern Ireland and shows the wreck of the Lusitania, torpedoed early in the last war. Salvage operations on land, calling for the location of buried munitions dumps, shells and practice bombs, may be aided by electric prospecting. Large masses of buried metals have been located by electric potential, electromagnetic and straight magnetic prospecting. Small objects buried at shallow depths may be discovered by means of portable high frequency devices commonly known as "treasure finders." The same methods are also applicable to the location of hostile weapons, munition dumps, shells, bombs and so forth.

If any proof were needed for the military significance of meteorology, our newspapers and radios brought it to us shortly after the start of the present hostilities. Weather forecasts and the dissemination of information on the wind, air pressure and temperature have been entirely eliminated or restricted to very short periods. Even far inland, the broadcasting of meteorologic data may give important clues to weather-wise enemies operating off the coast. Conversely, accurate weather information is indispensable for the operations of friendly forces on land, in the air and at sea. Accurate instantaneous meteorologic data are required in sound-ranging location and artillery adjustment, and for the operation of sound locators, since the velocity of sound is dependent on the temperature of the air and the direction and speed of the wind.

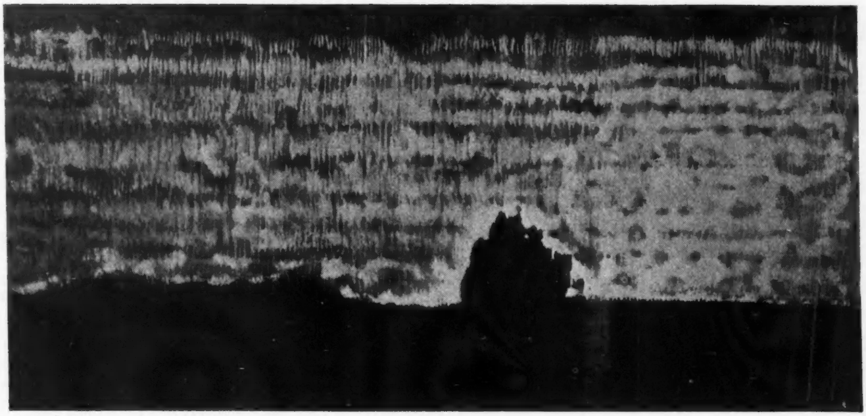

FIG. 2. Sonic depth record of the wreck of the *Lusitania* [after D. H. McMillan].

A large number of problems of direct or indirect military significance require the investigation of foundations and the location of suitable construction materials. Such problems include the construction of fortifications, shelters and harbors; the planning and building of highways, railroads, canals, tunnels and bridges; the construction of ordnance and munitions plants, and various irrigation, flood control, drainage and power projects. Prominent in these applications have been seismic refraction, dynamic soil testing and electric resistivity methods.

The ***seismic refraction method*** involves a measurement of the travel times of explosion-generated elastic impulses as a function of distance. The time-distance curves thus obtained make it possible to calculate the depths and the elastic wave velocities of geologic formations. Limestones, igneous rock and metamorphic formations, representing desirable foundation material, are characterized by high velocities, whereas the opposite is true of unconsolidated overburden materials such as sand, gravel, fluviatile and glacial formations. The U. S. Army Engineers, the Bureau of Reclamation and the Bureau of Public Roads have conducted numerous seismic investigations of irrigation, flood and power control and highway projects. Figure 3 shows the

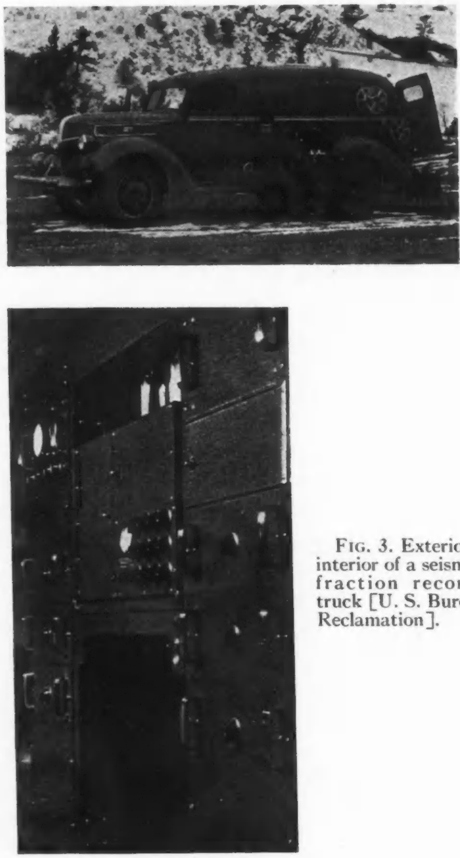

FIG. 3. Exterior and interior of a seismic refraction recording truck [U. S. Bureau of Reclamation].

exterior and interior of a 6-trace refraction equipment of the Reclamation Bureau.

Nondestructive foundation investigation by means of continuous elastic waves is the function of the *dynamic soil testing methods*. The impulses are generated by vibrators of variable frequency and are recorded by seismic detectors at a number of nearby stations. The travel time of the impulses as a function of distance yields the wave velocity, which is closely related to the degree of consolidation of the near surface mediums. The amplitude, likewise as a function of distance, provides information on absorption, damping and refractions and reflections from subsurface strata. At any given point, the amplitude as function of frequency—the "resonance curve"—yields the damping factor and the natural frequency of near-surface formations. This frequency is related to the bearing strength. Dynamic soil tests have been used to test gun emplacements, highway and railroad beds, bridge and overpass approaches and the like.

Electric resistivity methods are useful for the determination of depth to bedrock and for the location of construction materials. In the four-electrode technic, the external pair is supplied with a measured current from a battery while the potential difference of the internal pair is observed. The ratio of potential difference and current, multiplied by a factor depending on the electrode spacing, yields the ground resistivity, which is a true resistivity so long as the ground is homogeneous. When different formations occur below the surface, an apparent resistivity is observed which is a function of the true resistivities and geometric arrangement of the formations. If the electrodes are moved over the ground with constant spacing (constant depth penetration), the observed resistivity variations indicate lateral changes in the formation resistivities and their thickness; this is called *resistivity mapping*. If measurements are taken with continuously increasing electrode separation—*resistivity sounding*—apparent resistivities may be plotted as a function of spacing or depth. Both procedures have been used by various commercial and government agencies for the testing of dam sites and highway foundations, the location of construction materials and harbor investigations. Figure 4 illustrates the application of resistivity sounding (left) and resistivity mapping (right) in harbor work.

In munitions plants where low resistance ground connections must be provided to guard against discharges of static electricity, resistivity measurements will determine the thickness and conductivities of formation members, whereby

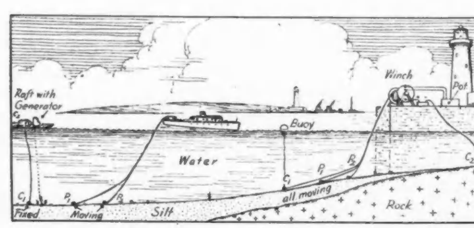

FIG. 4. Resistivity sounding (left) and resistivity mapping (right) in harbor investigations.

the resistance of a single grounding stake, and thus the number of such stakes required to attain a specified ground resistance, may be obtained. Figure 5 shows three typical curves for one, two and three layers, with interpretations.

Resistivity methods are useful in prospecting for ground water. This application heads the list of problems in the second group referred to at the beginning of the article; namely, those concerned with the location of mineral resources. Though generally at shallow depth, ground water is not too readily located since the reactions depend a great deal on the geologic occurrence of the water-bearing beds. Moreover, the water may be a poor conductor—when percolating through mediums of high permeability—and again it may be a good conductor—when mineralized by extended contact with the aquifer. When resistivity methods are used to map salt water contaminations, which have higher conductivities, the interpretation of the field data is somewhat simplified. In artesian basins, where the accumulation of water is controlled by regional geologic structure and where the aquifer (or a stratigraphically related bed) is characterized by sufficient elastic-velocity contrast, seismic refraction and reflection methods may be used to advantage (Fig. 6). Geophysical logs of water wells obtained with the help of electric resistivity and temperature measurements will often give valuable clues to depth, quality and yield of water-bearing formations.

In modern mechanized warfare, probably no single mineral is as important as petroleum. Not only is petroleum indispensable as the source

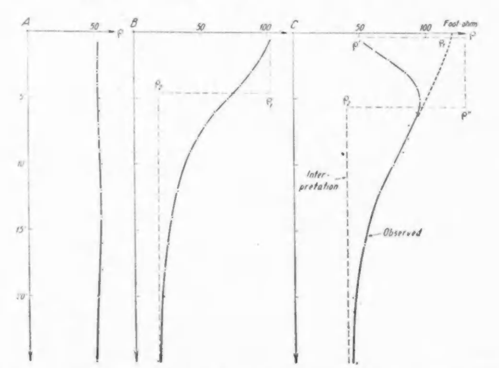

FIG. 5. Static-ground resistivity curves for one, two and three layers.

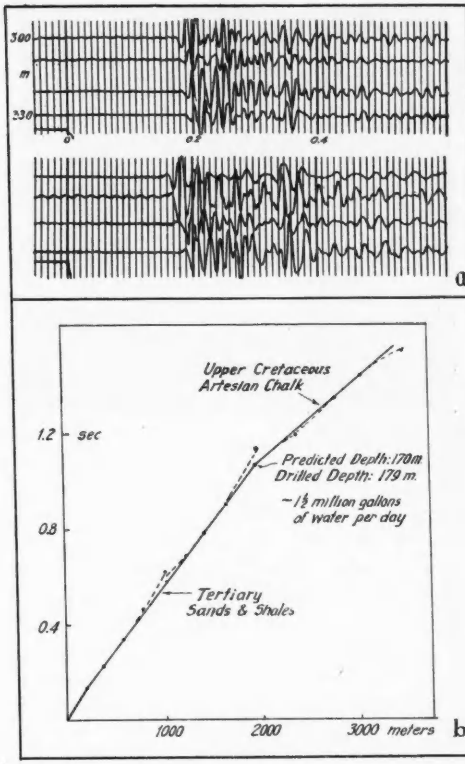

FIG. 6. Refraction travel time curve, artesian basin in Tunisia [after R. P. deCeccaty and M. Jabiol].

material for motor fuels and lubricants for countless machines of war, but it plays an equally important role in many industries engaged in war production. The increased requirements for oil production can in the end be met only by an accelerated rate of discovery of new fields; geophysics must be relied on more than ever to do its part in finding new oil deposits. To the oil operator, geophysical methods need no introduction; they are said to have accounted for five to six billion barrels of new oil and are now estimated to involve the expenditure of 25 million dollars annually for field work and laboratory research.

Geophysics approaches the problem of oil location indirectly by mapping geologic structure favorable to oil accumulation. A rapid reconnaissance instrument is the *gravity meter*, an extremely sensitive spring balance that measures

FIG. 7. Split-spread reflection seismic shot [Heiland Research Corporation].

gravitational acceleration with an accuracy of 1 part in 10^7 and thus reveals anomalies caused by anticlines, salt domes, buried ridges and faults. Magnetically effective oil structures may be located with the magnetometer. Most widely used at present is the *seismic reflection method* (Fig. 7), which involves the measurement of the time interval between a dynamite explosion and the return of the reflected elastic wave from subsurface beds. Such depth determinations are currently made with an accuracy of better than 0.5 percent of depth. Attempts to locate oil directly have also not been lacking. Most promising are geochemical methods that rely on the measurement of small quantities of hydrocarbons in soil samples collected from shallow wells.

Geophysical methods have contributed to an increase in production efficiency. This is especially true of the well logging methods, which involve the measurements of such physical parameters as electric resistivity, natural potentials (related to rock-porosity), radioactive radiations, temperature and so forth.

Although it is doubtful whether a scarcity of coal and lignite will develop, it should be mentioned that various geophysical methods have been used successfully for their location. It has been possible to trace coal seams directly by electric resistivity methods; geologic structures in coal-bearing regions have been mapped by seismic refraction and reflection shooting. Lignite has been located directly and indirectly by various gravitational methods.

In comparison with the first World War, the speed and size of airplanes, ships and tanks, the range and power of guns and projectiles and the strength of armor plate have increased—almost entirely as the result of progress in metallurgy. The need for alloying metals, such as chrome, manganese and tungsten, and for lightweight metals such as magnesium and aluminum, is now greater in proportion. Many of these "strategic" metals are not produced domestically in quantities sufficient to meet the war demands, and various steps have been taken to alleviate the situation. Among them are the accumulation of stock piles, restrictions in nonessential consumption, the perfection of new processes, the adoption of substitutes and the development of new resources by drilling and by geologic and geophysical methods.

The Strategic Minerals Act of 1939 provides for an annual appropriation of $150,000 to the U. S. Geological Survey and $350,000 to the

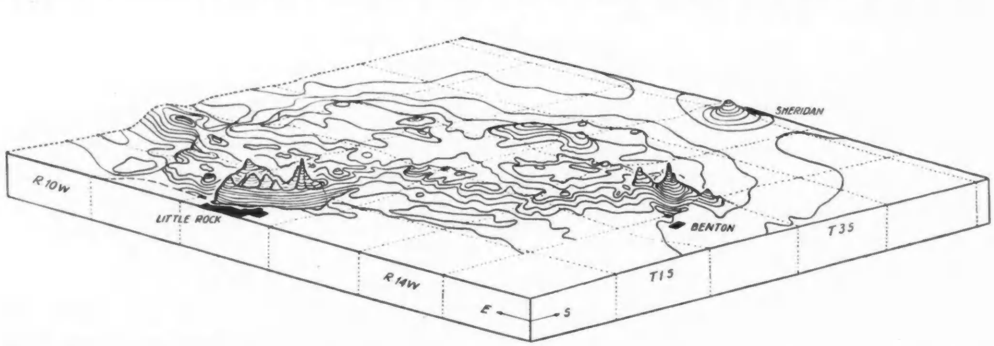

FIG. 8. Magnetic anomalies on igneous rocks associated with bauxite deposits in Arkansas [after N. H. Stearn].

Bureau of Mines for the study of domestic sources of strategic minerals. A large amount of geologic and geophysical exploration has been done by both agencies, and the results of some of these studies have been published.

Geophysical exploration for metallic minerals is more difficult than geophysical oil exploration. Deposits of metallic minerals are usually smaller than the average oil structure; the geology is more complex and difficulties arise from adverse transportation and terrain conditions. Frequently the approach is indirect in that the geophysicist is concerned with the location of geologic structure and of other minerals that may be associated with the ore to be located. A pertinent example is furnished by the aluminum ore (bauxite) deposits in Arkansas which occur as weathering products on intrusive igneous rocks. These igneous rocks can be located under the cover of younger sediments by magnetic, gravitational and seismic exploration. Figure 8 represents the magnetic anomalies that were mapped by N. H. Stearn in the area near Little Rock and Benton some ten years ago.

Chromite is another mineral on the strategic list that has been the object of extensive geophysical study. Since it usually occurs in ultrabasic igneous dikes, magnetic methods have been applied for the location of the host rock. At times the ore bodies are sufficiently large and differ enough in their magnetic permeability and density from the basic rocks to produce, by themselves, magnetic and gravitational anomalies. A comparatively small amount of work has been done on manganese deposits, chiefly magnetic and electric, to map associated formations and geologic structure. The same is true of mercury (cinnabar) deposits which, by themselves, are too small and physically ineffective. However, magnetic and electric methods have been useful in tracing igneous rocks, shear zones, faults and fissures on which manganese and cinnabar are apt to occur.

Most of our nickel, a metal used extensively for the alloying of cast iron, steels and nonferrous metals, comes from the Sudbury Basin in Canada, where the iron nickel sulphide (pentlandite) is found in close association with pyrrhotite. The ore bodies there give almost "textbook response" with electric, magnetic and gravitational methods. Some typical results, showing the magnetic and electric data, are reproduced in Fig. 9 for the Falconbridge ore body. Another

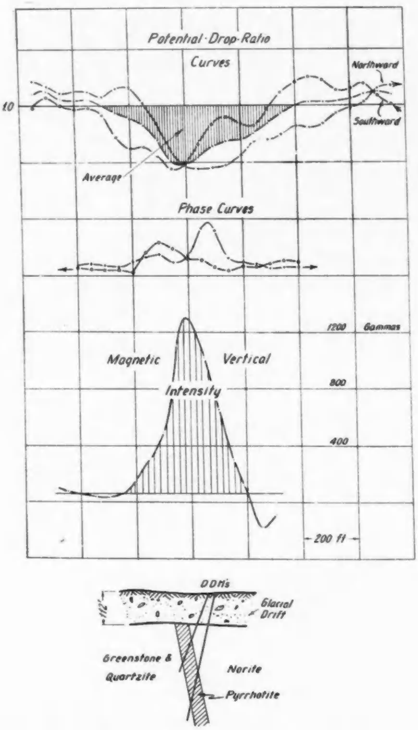

FIG. 9. Electric and magnetic results on Falconbridge nickel orebody [after Lundberg].

very strategic mineral, tin, occurs in conjunction with acid intrusives or in placer deposits, as in Malaya. It is possible, under such conditions, that an indirect method of locating associated magnetite concentrations and determining depth to bedrock may be useful. Tungsten ore, when occurring in shear or fault zones, may likewise be located indirectly by electric and magnetic methods. Of interest in this connection is a report that drill-core examination by fluorescence, or under ultraviolet light, has aided materially in the discovery of a scheelite ore body in Idaho.

The foregoing are merely a few examples illustrating the possibilities of geophysics in prospecting for some of the strategic minerals. Shortages have developed and will continue to be

felt in other minerals, such as copper, lead and zinc, and geophysics can be depended upon to give some help in finding new or in extending old deposits of that type. Other applications in mining not directly related to the location of specific deposits include measurements of overburden thickness, regional geologic studies beyond the limits of a prospect, investigations of mine caving, rock bursts and the like.

It is safe to predict that geophysical exploration will receive considerable stimulus because of the vastly accelerated needs for fuels and minerals, and the question naturally presents itself, what is going to happen to geophysics after this war is over. The devices that were invented for the detection and destruction of the enemy will fade out of the picture but will, nevertheless, stimulate developments in related technics or have peacetime applications later. Prospecting for wartime minerals will be abandoned, but in its place will come a period of extensive exploration for materials needed in reconstruction, not merely in this country, but in nearly every country of the globe.

The Names of Physical Concepts

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We have to use language, which deals necessarily with preconceived ideas. Such ideas unconsciously held are the most dangerous of all.

—H. Poincaré

I feel that many . . . who deal with mechanics would understand the concepts far better if these ideas were represented by Latin words rather than words of ordinary speech. Scientists are only men and use language in the common way for most of their lives. They are subject to all the confusions of speech of common men and succumb to them all too often.

—R. von Mises

"When I use a word . . . it means just what I choose it to mean—neither more nor less."
"The question is," said Alice, "whether you can make words mean so many different things."
"The question is," said Humpty Dumpty, "which is to be master—that's all."

—C. L. Dodgson

The purpose of this paper is twofold: first, to point out the inconsistencies in the present names of physical concepts and the troubles caused by these names; and second, to suggest a systematic way of naming concepts. Even though the older names may be too firmly fixed by tradition to be supplanted, it is hoped that the method may at least be helpful in the naming of new concepts as they are introduced.

This paper will be limited to the concepts of physics. However, this limitation does not imply that the terms used in physics are worse than those used in other sciences. Indeed, the mathematician has shown himself to be a Procrustean genius in fitting common words into places where they do not belong, while the psychologist and the economist deal with subjects that are still at a level where no amount of linguistic reform can possibly be of much help.

In any branch of science, it becomes necessary to introduce certain exact concepts. These concepts differ from the ideas associated with ordinary speech principally in the precision of their definitions, which are purposely made on a different level from the definitions of everyday life. That each new scientific concept should have a new name to distinguish it from other scientific concepts and from things of the lay world seems too obvious a requirement to mention. Actually, however, new concepts have not always been given new names, and with a few exceptions the scientific concept has had to struggle along under a name that is used for many other ideas.

When a scientist invents a new concept, common practice seems to be for him to try to draw an analogy between it and something in the world of common experience. The common name is then applied to the new concept, and this procedure is supposed to provide a mental bridge over which the beginner can pass from the lay world to the realm of science. That it does provide a bridge is evident to anyone who takes the trouble to listen to a lecture on elementary mechanics ("All of you know what *work* is. Well, that is what we are

going to talk about today.") or optics ("Everyone knows what *brightness* is. Let us denote it by *B*. Then, obviously, ...")

The trouble with the bridge—to continue the simile—is that it seems so broad and so easy that most users forget that there is a chasm. There is constant confusion between the vague, popular idea and the exact scientific concept having the same name. Secondary school students of a decade ago were shocked when told that they were doing no *work* when holding a heavy weight at arm's length. Most of them never really understood that the difficulty was a direct consequence of using the same word for two different things, one a vague idea associated with physical fatigue and the other an exact concept of force times distance.

Nor is such confusion confined to the secondary school. The scientist and engineer are constantly on their guard against the confusion of the dual aspects of scientific words, but they do not always succeed in avoiding the trouble. A classical example is the 75-year dispute between the followers of Leibniz and those of Descartes over some of the concepts of mechanics. Similar meaningless disputes, based purely on multiple meanings of scientific words, occur today. It is only recently that the importance of mental confusion caused by words has been fully realized; and the new science of semantics[1] gives some idea of the widespread tendency to confuse the word with the thing, to confuse levels of abstraction, to use a multiple-meaning word in several of its different meanings in the same sentence or in the same argument. The use of a new word for each scientific concept will not prevent all confusion caused by words, but it will certainly reduce errors in a field where such reduction is of prime importance.

1. REQUIREMENTS FOR A NAME

The name of a scientific concept should satisfy four requirements: (1) unambiguity, (2) internationality, (3) simplicity, (4) euphony. Judged by this standard, the present names of concepts make a very poor showing. Most of them fail under (1), for there is always a possibility of confusion when a word that is already in the dictionary with one or more popular meanings is appropriated as the name of a scientific concept. Among such unsatisfactory words are *work*, *force*, *power*, *efficiency*, *charge*, *heat* and *brightness*.

Most of the words fail also with respect to *internationality*. The question of what terms are in use outside his own nation seems to be completely ignored by the average scientist and engineer. It is true that various international organizations have done valuable work in standardizing definitions, names and units; but the result has been far from ideal. The extensive dictionary of the International Electrotechnical Commission,[2] for example, seems to be little more than the literal translation of inappropriate words from one language to another.

Table I gives a list of common scientific names in six languages. Note that in the few cases where a word has been introduced directly from the Greek—*energy* and *entropy*, for instance—this word has been accepted with little or no change by all the language groups. The more anthropomorphic words, however, have been translated with painstaking fidelity into each language. French and English words tend to be very similar—mass, *masse;* energy, *energie;* for instance—though there are exceptions—efficiency, *rendement;* voltage, *tension*. The corresponding words in German, Russian, Dutch and the Scandinavian languages are generally quite different from English, and the reader must memorize corresponding terms. Who among the uninitiated would know, for instance, that *Leuchtdichte* means *brightness* and *Lichtstärke* means candlepower? While lack of internationality is less likely to cause trouble than the ambiguity produced by dual-purpose words, it is a possible source of misunderstanding and one that can be eliminated by a proper choice of names.

The lack of *simplicity* is likewise evidenced in many of the present names of concepts. It is a surprising fact that some of the concepts, particularly in electricity and magnetism, have several names, none of which is very good and none of which has been able to gain the ascendency. This is not simplicity. Again, some

[1] C. K. Ogden and I. A. Richards, *The meaning of meaning* (Harcourt, Brace, New York, 1938); A. Korzybski, *Science and sanity* (New York, 1933); Stuart Chase, *The tyranny of words* (Harcourt, Brace, New York, 1938); A. M. Weinberg, "General semantics and the teaching of physics," Am. J. Phys. [Am. Phys. T.] **7**, 104 (1939).

[2] *International electrotechnical vocabulary* (International Electrotechnical Commission, London, 1938).

TABLE I. Names of concepts.*

English	French	German	Italian	Spanish	Esperanto
mass	masse	Masse	massa	masa	maso
length	longueur	Strecke	intervallo	longitud	distanco
time	temps	Zeit	tempo	tiempo	tempo
energy	energie	Energie	energia	energia	energio
power	puissance	Leistung	potenza	potencia	potenco
force	force	Kraft	forza	fuerza	forto
pressure	pression	Druck	pressione	presión	premo
efficiency	rendement	Wirkungsgrad	rendimento	rendimiento	efikeco
electric charge	charge	Ladung	carica	carga	ŝargo
electric intensity, field strength	intensité de champ, force électrique	Feldstärke	forza elettrica, intensità di campo	intensidad de campo	kampa intenso
electric flux	flux électrique	Fluss	flusso elettrico	flujo eléctrico	flukso
flux density	induction électrostatique	elektrische Verschiebung	induzione elettrostatica	inducción electrostatica	elektra indukdenso
electric current	courant	Stromstärke	intensità di corrente	intensidad de corriente	fluintenso
potential	potentiel	Potential	potenziale	potencial	potencialo
voltage	tension	Spannung	tensione	tensión	tensio
time constant	constante de temps	Zeitkonstante	constante di tempo	constante de tiempo	tempo-konstanto
magnetic field strength	intensité de champ	magnetische Feldstärke	intensità di campo	intensidad de campo	kampa intenso
magnetic flux	flux magnétique	magnetischer Fluss	flusso magnetico	flujo magnetico	magneta flukso
flux density	induction magnétique	magnetische Induktion	induzione magnetica	inducción magnetica	magneta indukdenso
quantity of heat	quantité de chaleur	—	calore	cantidad de calor	—
temperature	température	Temperatur	temperatura	temperatura	temperaturo
entropy	entropie	Entropie	entropia	entropía	—
luminous flux	flux lumineux	Lichtstrom	flusso luminoso	flujo luminoso	lumoflukso
illumination	éclairement	Beleuchtungsstärke	illuminazione	iluminación	grado de lumigo
luminosity	radiance	spezifische Lichtausstrahlung	luminosità radianza	radiancia	radieco
brightness	brillance	Leuchtdichte	splendore	brillo	helodenso
quantity of light	quantité de lumière	Lichtmenge	quantità di luce	cantidad de luz	lumokvanto
exposure	excitation	Belichtung	eccitazione	—	—
luminous intensity (candlepower)	intensité lumineuse	Lichtstärke	intensità luminosa	intensidad luminosa	lumintenso
visibility	coefficient de visibilité	photometrisches Strahlungsäquivalent	fattore di visibilità	coeficiente de visibilidad	faktoro de helimpreseco

* Based on *I.E.C. vocabulary* (reference 3) and *International lighting vocabulary* (Commission Internationale de l'Eclairage, Teddington, 1938).

names are burdened by "quantity of"—*quantity of heat*, *quantity of electricity*—"intensity"—*intensity of magnetization*, *intensity of current*, *light intensity*, *sound intensity*, *intensity of stress*—or "strength"—*field strength*, *magnetic pole strength*. Since all of the concepts are quantitative, the inclusion of "quantity," "amount" or "intensity" is redundant. Simplification can be effected by choosing names that do not contain such superfluous elements.

2. SUFFIXES

A valuable tool in the introduction of simplicity into a system of concepts is the use of standardized prefixes or suffixes. An examination of existing names shows two such standardized word endings that have obtained considerable importance and whose further use should be encouraged. These endings are *-ity* and *-ance*, and their meanings seem to be as follows: *-ity* = property of a material, as in *density*, *viscosity*, *conductivity*, *re-*

sistivity, permittivity, permeability, reluctivity, susceptibility; -ance = characteristic of a body, as in *conductance, resistance, elastance, impedance, capacitance, susceptance, admittance, inductance, reactance, permittance, permeance, reluctance.*[3]

All these words are in established scientific use. It is true that a few of them have popular meanings, but this slight degree of duality seems hardly important enough to require new words. It should be pointed out also that there are exceptions to the foregoing meaning of the suffix *-ity*, as in *intensity, flux density, velocity, audibility*. But most of these words could well be replaced by something better. The reader may also think of the expression, "electric capacity of a condenser," where "capacity" is used as a property of a device instead of a property of a material. However, the expression is being replaced in modern scientific literature by *capacitance of a capacitor*, which is in agreement with the recommendation of this paper.

No other standardized endings for scientific words seem to be in use, either in English or in other languages. This fact, however, does not prevent the introduction of as many such standardized endings as seem useful. One extreme would be to select a root word to designate the general subject—a word for heat flow, one for acoustics, another for mechanics—with a large number of endings to specify the particular concept. The other extreme would be to use no standardized endings but to make up a new word for each concept. A compromise seems best: Use a small number of standardized endings referring to very closely allied concepts, for each group of which a separate basic word is selected.

It is suggested that three endings be used, corresponding to quantity per unit length, quantity per unit area and quantity per unit volume. For example, a word would be selected to replace the term *electric charge*. The use of the three suffixes would then give a set of four closely related terms dealing with the four concepts of charge, charge per unit length, charge per unit area and charge per unit volume. Other possible suffixes would indicate quantity per unit time, the product of quantity and time and the product of quantity and distance. These particular concepts, however, are felt by most people to be rather distantly related to the original quantity, so special endings for them are not recommended.

The three recommended endings are:

-ent = per unit distance,
-age = per unit area,
-um = per unit volume.

These endings are arbitrary, though the word "gradient" suggested the first, while x-ray "dosage" suggested the second. The endings are short and easily remembered, and there appears to be nothing to prevent their employment in international scientific words, used unchanged in the various European languages.

3. CHOICE OF WORDS

In the choice of words for the basic concepts, one may employ several methods:

(1) The coining of new words.
(2) Use of words from living languages.
(3) Use of words from dead languages, such as Latin, Greek, Sanskrit.

In (1) the composer makes arbitrary combinations of the 26 letters of the alphabet and discards those combinations that are already in English or other languages or that are not euphonious; the method has interesting possibilities, though ordinarily the words are hard to remember. The second method must be ruled out on the basis of internationality; even if the world could be persuaded to adopt the concept names used, say in the U.S.S.R., the Russians would be left in the old predicament of using the same words for scientific and lay concepts.

The third possibility seems, on the whole, the best one. Latin words cannot be used because they are so much a part of English and the Romance languages and would therefore cause trouble with dual meanings. It is natural, therefore, to turn to Greek, particularly since Greek has already been used so extensively in scientific literature (medical terminology, for instance). The ancient Greek language contains a great many words that do not resemble anything in the English dictionary and are yet sufficiently euphonious for adoption. Greek has the advantage over Sanskrit that it is easier for the Western world.

[3] Other endings which have become standardized but which are not applicable to the present work are: *-or* = device (*motor, generator, reactor, resistor, radiator*); and *-ion* = process (*irradiation, illumination, convection, transmission*).

Table II. Proposed names.

Present name	Proposed name	Derivation
mass	mass	
length	length	
time	time	
energy	energy	
energy per unit volume	ergum	ἔργον = work, -um = per unit volume
power	dynatos	δυνατός = strong, powerful, mighty
force	kratos	κράτος = force, strength
stress	kratosage	-age = per unit area
pressure	kratosage	
efficiency	merance	μέρος = part, -ance = property of a device
electric charge, quantity of electricity	elektros	ἤλεκτρος = amber
charge per unit length	elektrosent	-ent = per unit distance
charge per unit area	elektrosage	-age = per unit area
charge per unit volume	elektrosum	-um = per unit volume
electric intensity, field strength	protos (electric)	πρῶτος = first, earliest
electric flux	telos (electric)	τέλος = result, an end accomplished
flux density	telosage (electric)	-age = per unit area
current	salos	σάλος = the rolling swell of the sea
current density	salosage	-age = per unit area
potential	potential	
potential difference, voltage, electromotive force	proteus	Πρωτεύς = one of the gods
time constant	chronance	χρόνος = time, -ance = property of a device
magnetic intensity, field strength	protos (magnetic)	πρῶτος = first, earliest
magnetic flux	telos (magnetic)	τέλος = result, an end accomplished
flux density	telosage (magnetic)	-age = per unit area
magnetomotive force	proteus (magnetic)	Πρωτεύς = one of the gods
quantity of heat	energy (thermal)	
heat per unit volume	ergum	ἔργον = work, -um = per unit volume
temperature	temperature	
entropy	entropy	
luminous flux	pharos	φάρος = a lighthouse
flux density, illumination, luminosity	pharosage	-age = per unit area
brightness	helios	ἥλιος = the sun
brightness per unit thickness of source	heliosent	-ent = per unit distance
quantity of light	phos	φῶς = light
exposure	phosage	-age = per unit area
visibility	lamprosity (spectral)	λαμπρός = brilliant (as of colors)
luminous efficacy	lamprosity (total)	-ity = property of a substance

The Greeks had a word for many things, but obviously they did not have words for the concepts needed here. However, the language, like modern German, builds up words by the addition of others, to obtain various meanings that the ancient Greek did not need. Time spent with several Greek scholars resulted in the building of such masterpieces as

palinoptomerid = the fractional part of the light reflected from a surface (πάλιν = back, ὀπτ = see, μέρος = part),

dialampomerid = the fractional part of the light that is transmitted (διά = through, λάμψις = shining, μέρος = part).

Words of this kind, composed in the classical manner, were without exception too long and complicated. I therefore decided to forsake the classical scholars, who were satisfied only with this sort of literal translation, and to pick words from the Greek lexicon—words that had some slight relation to the desired subject. To combine these words with the arbitrary endings of Sec. 2 will of course, horrify the purist.[4] But he is probably accustomed to such things by now—in such hybrids as *telephone*, *cablegram*, *speedometer;* and in Interlingua (*Latino sine flexione*) and other international languages, which must certainly be regarded in some quarters as mutilations of classical Latin. Such objectors[4] were therefore disregarded and a set of proposed names was formulated (Table II).

[4] See H. W. Fowler, *Modern English usage* (Oxford, 1934), p. 242.

4. PROPOSED NAMES

In Table II no attempt has been made to include all the concepts of physics, though most of the important ones are considered.[5] *Mass* is an international word so there is no need to change it. The scientific use of *length* and *time* is so intimately associated with the popular use that there seems to be no advantage in altering the words. If, at some future time, astronomical lengths and sub-microscopic lengths are considered as separate concepts, as suggested by Bridgman,[6] they should be given new names to distinguish them from the kind of length that is measured with a meter stick.

The large number of words that represent properties of materials and characteristics of devices or bodies are generally satisfactory and are not included in Table II. Exceptions are new words for *efficiency* and *time constant.* Engineers use "efficiency" to mean almost anything—"efficiency of the workers," "mental efficiency," "visual efficiency"—and thus there is advantage in using a new international word such as *merance* to designate the ratio of output to input of a machine. Similarly, *chronance* may be used as a simple and international substitute for the term "time constant." The word *lamprosity*[7] is suggested for the concept now variously called "visibility," "luminosity," "luminous efficiency" and "luminous efficacy."

If a prize were offered for the present names that are most clumsy, redundant and ambiguous, the electromagnetic group undoubtedly would win. The use of the word "flux" in electrostatics and magnetostatics is peculiar, in view of the absence of anything that is flowing. "Electric intensity" and "magnetic intensity" are cumbersome and not very precise. Any simple Greek words might be preferable to the old terms. Since, however, it is often convenient to think of the "field strength" as the fundamental quantity which produces the "flux," I have chosen the words *protos* and *telos* which suggest *cause* and *effect.* The same words are used in corresponding electric and magnetic concepts, with qualifying adjectives when necessary.

The terms used most frequently by the electrical engineer are probably "current" and "voltage." Neither is likely to cause confusion, though both are clumsy. For current, an attempt was made to get a Greek word that suggested flow, movement, diffusion; but the available words seemed to be peculiarly non-euphonious. *Potamos* (ποταμός = river) is a possibility. The word finally selected, however, was *salos.* Field strength is closely associated with voltage, so similar words for the two concepts would be preferable. *Protos* and *proteus* were selected. The ending *-eus* may be considered, if desired, as an indication of the multiplication by distance of an *-os* concept.

It seems likely that a critical survey of physics may eventually lead to radical changes in the concepts themselves, and such a study should logically precede the establishment of names. Needless to say, no such general survey has been attempted here. The photometric and radiometric concepts, however, appear to be particularly bad and a suggested reform is given in Table II and in greater detail elsewhere.[8]

The pronunciations of the names of Table II can be established very easily. The stress will be on the penultimate syllable (exceptions, *hel'i os* and *pro'te us*). The letters will be pronounced as in most European languages, with *a* always as in *father*, *i* as in *machine*, *o* as in *ohm* and *e* like the *a* in *hate.* The proposed words can be incorporated into the various languages without change, as a frankly "foreign" element. Such a procedure has already occurred with a number of scientific words of Greek origin.

5. OBJECTIONS TO THE PROPOSED NAMES

Any reform in the names of physical concepts will be dismissed by most people as "visionary," "impracticable" and "unnecessary." It will be classed with other "impracticable" schemes such as the reform of the calendar, the use of an auxiliary international language or the introduction of the metric system. It should be noted,

[5] See, for example, A. E. Kennelly, "I.E.C. adopts mks system of units," Trans. A.I.E.E. **54**, 1373 (1935); W. H. Hall, "The foundation of systems of units," J. Frank. Inst. **225**, 197 (1938).

[6] P. W. Bridgman, *The logic of modern physics* (Macmillan, New York, 1932).

[7] P. Moon, "Basic principles of illumination calculation," J. Opt. Soc. Am. **29**, 108 (1939).

[8] P. Moon, "A system of photometric concepts" (to be published in J. Opt. Soc. Am.).

however, that the system of names advocated in this paper does not require the overthrow of any established custom, nor does it require a world-wide agreement or the action of an international organization. I have merely suggested alternate names for concepts, many of which have several names. It is the privilege of the author of any paper or book to use the nomenclature that he finds most suitable. If, therefore, he finds that some or all of the names of this paper are suitable for his purpose, he is free to use them. If they prove to be of value in promoting more exact thinking, they may gradually gain in popularity. No revolution is required.

The principal objection that will be raised to any new set of names for physical concepts is undoubtedly that they are *unnecessary*—the scientific world has managed to get along for several hundred years with a very unscientific and inconsistent vocabulary, meanings can usually be deduced from the context, and any change is ordinarily regarded as futile. If the reader does not accept the thesis that the use of words having several meanings tends toward muddled thinking, little more can be said. However, the entire history of science has shown a continuous trend toward more exact thinking, more precise definitions and a deeper grasp of the nature and limitations of what is being done. In mathematics there has been a trend toward greater rigor. The old intuitive idea that "In the pure mathematics we contemplate absolute truth which existed in the divine mind before the morning stars sang together" is now to be contrasted with Hilbert's idea[9] that mathematics is merely a man-made game played according to certain arbitrary, man-made rules. In physics, relativity and the quantum theory have led to a somewhat similar intellectualization of the basic ideas. There is every reason to believe that this movement will continue and that the use of popular words to represent scientific concepts will prove an increasing hinderance to logical thinking.

Another objection that will be made is that the learning of new names is difficult and will constitute a handicap to the study of science. The same objection might be directed against the coining of new names for new devices. Yet no wail of protest seems to have gone up on the introduction of such words as ***automobile, radio, kenotron, cyclotron, colorimeter, bolometer.***

I have also been told that new scientific words, introduced now, will gradually find their way into the common language and will thus lead, during the course of the next century, to the very duality of words which we are trying to avoid. If true, this may prove troublesome to future generations but need not prevent the present generation from taking whatever steps it finds convenient.

6. CONCLUSIONS

The present system of names of physical concepts has grown up in a haphazard way and has resulted in words having two different meanings: (1) a vague, popular meaning (or several of them); (2) an exact scientific meaning. This duality of meaning tends to cause confusion, even among scientists and engineers, and has been the basis of many of the most heated arguments in the literature of science. It is proposed that the present names of concepts be replaced wherever desirable with a more consistent set of new names which have no counterpart in the English dictionary.

In making such a change, one can also satisfy the requirements of internationality, simplicity and euphony. The new terms can be such that they do not conflict with words in use in any of the important modern languages, and they can be incorporated without change into these languages. This will be of value in the reading of the foreign scientific literature and will tend to reduce misunderstandings. Also, the introduction of new words allows many of the clumsy expressions now in use to be simplified and made more euphonious.

Besides the present standardized endings of *-ity* and *-ance*, three new endings are suggested: *-ent*, *-age* and *-um*, corresponding, respectively, to the meanings "per unit length," "per unit area" and "per unit volume." This step results in considerable gain in simplicity and precision. The various endings are applied to Greek words which are selected to give at least a slight suggestion of the desired meaning. A list of proposed names of concepts is given. Other concepts, if needed, can be named in a similar manner.

[9] David Hilbert and P. Bernays, *Grundlagen der Mathematik* (Springer, Berlin, 1934).

Some Stepped-Up Lecture Table Experiments

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1. IN the days of our youth, what mingled joy and sorrow came with the sound of the old steam calliope that brought up the rear of the circus parade! Its wail could be heard for blocks and it sounded like nothing else on earth but itself. As it came down the street playing "Hot time in the old town," each note took a sharp rise of pitch as each pipe started to speak. It was music to our ears then, and only in later years did we learn to rationalize the calliope and see that the upswing of pitch was caused by the increased velocity of sound in the pipes as steam replaced the colder air. Here is a nice example of how the velocity of sound is changed by change in various factors: the ratio of specific heats γ changes from 1.41 for air to 1.32 for steam; the density of the blowing gas changes for two reasons, changes in temperature and in molecular weight. Each note from a pipe blown with steam is higher by an interval of a fourth than the note from the same pipe blown with air at room temperature; that is, the frequency ratio is 3 : 4 or C : F.

As it is difficult to unravel the individual effects of temperature, gas density and γ from their combined effects in this case, it seems appropriate to demonstrate the temperature effect alone. One may blow two whistles simultaneously, starting both at the same pitch and temperature, and may then heat the air supplied to one of the whistles to show, by the appearance of beats, that the pitch of the heated whistle rises. However, since the velocity of sound varies with the square root of the absolute temperature, a much larger *change* in velocity is obtained by going *down* 200°C from room temperature than by going *up* the same number of degrees. Therefore, why not blow a whistle with air pre-cooled in liquid air? To accomplish this conveniently requires little more than a whistle and a test tube filled with liquid air. Connect the two and let the boiling liquid air supply compressed, cold air for blowing the whistle. However, to be sure that the *whole* system is cooled to the low temperature, the "boiler" shown in Fig. 1 is employed. It consists of a coil of copper tubing immersed in liquid air within a steel vessel made and capped with ordinary pipe fittings. A rubber stopper and

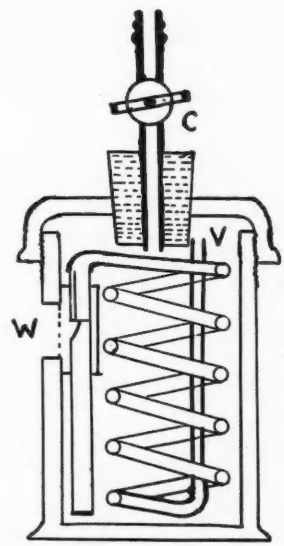

Fig. 1. Boiler for blowing a whistle with liquid air or with steam.

stopcock C control the pressure and act as a safety valve. As the liquid air boils away, it escapes through the vent V and blows a small whistle W also enclosed in the chamber but with access to the outside through the speaking aperture. The pitch of the whistle goes down from "do" to "fa," a ratio of frequencies (and hence of velocities) of 3 : 2, not quite as large a drop as might be expected on the basis of a simple temperature change from 300° to 90°K. This drop of pitch is easily recognized if the cold whistle is compared intermittently with another whistle which was tuned to unison with it when both were at room temperature.

This same boiler can be employed to show the rise in pitch when the whistle is blown with steam, as in the calliope, simply by introducing water instead of liquid air and then boiling the water over a burner. The over-all change in pitch from

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liquid air temperature to steam temperature is approximately *one octave*. Only a minor fraction of this change is attributable to the change from air to steam; a still smaller fraction is due to expansion of the whistle itself (and such expansion would *decrease* rather than increase the pitch). Most of the rise is directly ascribable to the fourfold rise in absolute temperature that occurs between the 90°K and 373°K.

2. There are those who believe that students have such a hard time with physics that one should never teach them anything but the most straightforward facts and should never confuse them with catch questions or paradoxes. I do not agree with this point of view, for I believe that there is no better way to arouse interest and to obtain independent thinking than by the judicious use of "puzzlers" thrown in now and then to pique the student's curiosity and to bring him sharply to attention. This may best be done after the student has already studied a topic and has cultivated a certain complacency that needs jolting. The following simple mechanical conundrum offers an excellent opportunity to trip the unwary. Two spring balances[1] are arranged with a light wooden frame as shown in Fig. 2*A*. The frame hangs from the hook of the upper balance, and within the frame hangs the second balance. A 1-kg weight is suspended from a pulley wheel attached to the hook of the lower balance. The lower balance therefore reads 1000 gm, and the upper one reads 1000 gm plus the weight of the frame and lower balance. Now suppose the weight were hung as shown in Fig. 2*B*, where one end of the string which holds the weight is linked to a screw-eye in the frame at *S*. What will each balance read? It is well to insert pins into each spring balance to hold it at zero while the change from *A* to *B* is made, and to get an expression of opinion from the students *before* removing the pins. Most students will be confident that the upper balance will read just what it did before; but the class is likely to split three ways with regard to the lower balance: some expect it to read 500, some 1000, and perhaps a few, 2000 gm. Now remove the pins, show the students what actually happens and let them try to account for the difference noted.

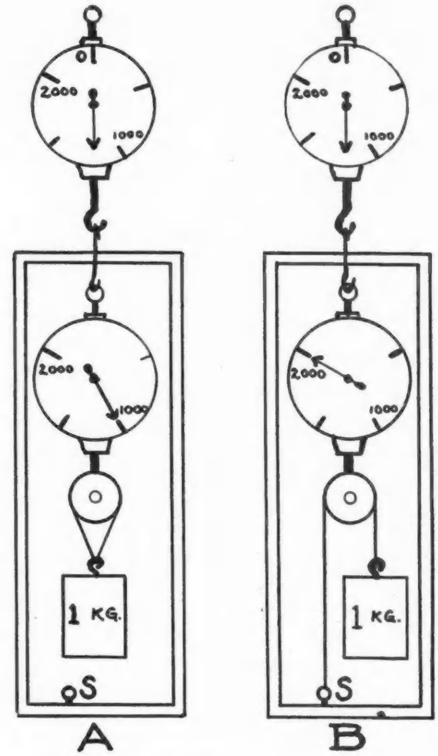

FIG. 2. A simple mechanical conundrum.

3. Nearly everyone has shown the experiment of collapsing a flat-walled tin can by atmospheric pressure, either by using a vacuum pump to exhaust the air or by boiling a small amount of water in the can to expel the air before stoppering it and removing it from the burner. The latter method is, to my mind, the better one; for, not only is the equipment readily provided, but the experiment demonstrates much good physics and its results arouse greater student interest than does the more obvious air-pump method. Moreover, after the can has been collapsed, it may be partially restored by boiling the water within it, thus making steam pressure undo the damage done by atmospheric pressure.

Here is a suggestion of another simple and effective way of showing the variation of vapor pressure with temperature and of demonstrating,

[1] I have made convenient dial balances by adding 8-in. cardboard dials and longer pointers to some new inexpensive 2-in. dial balances offered by W. M. Welch & Co., Chicago, Illinois.

at the same time, the large magnitude of atmospheric pressure. Into a 1-l flask (round bottom) pour two or three *teaspoonsful* of water and boil the water over a burner for a few moments; then close the flask with a single-hole rubber stopper through which extends a long piece of glass tubing (Fig. 3). Promptly raise the flask and insert the lower end of the tube into a beaker containing 800 cm^3 of colored water.[2] The flask will proceed to "drink" all of the water from the beaker with a rush and the experiment concludes with a loud "guzzling sound" like the sign-off of a chocolate milkshake. Here is water "running up hill" with no visible pump to propel it; everything is in sight and the final result is clear, although the cause of that result may not be obvious.

The experiment can also be shown on a large scale, provided one has a large airtight vessel to drain the lower reservoir. The height of the upper vessel may be increased far beyond arm's length, even to the top of a stepladder or to the ceiling of the room. It is best, in this case, to insert the stopper and to boil the water so as to expel air from the tube as well as from the flask. As soon as a good flow of steam issues from the mouth of the tube, the flask is ready. Numerous amusing

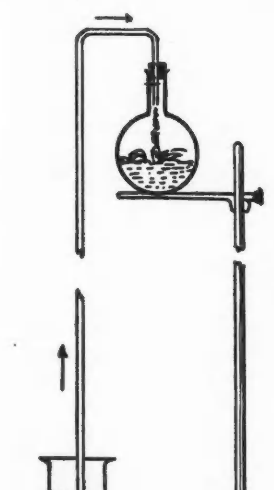

FIG. 3. Atmospheric pressure forces water into the flask as the vapor pressure within the flask decreases with decrease of temperature.

[2] Fluorescin in the water makes the experiment beautiful when shown in a darkened room under illumination from an ultraviolet source.

modifications may come to mind; for example, one might have a contest between this Robot and a student, offering to each the same volume of liquid to drain through equivalent tubes. We are a race of suckers, and the student *can* drink a milkshake through a five-foot "straw" if he is

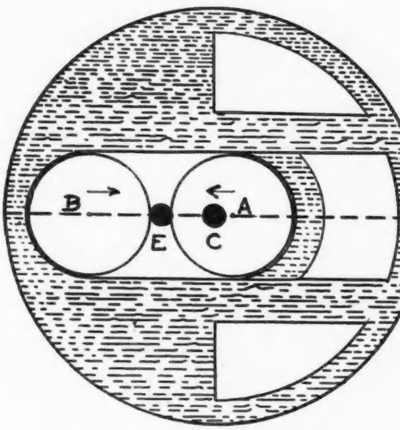

FIG. 4. Disk with shifting weight for demonstrating the dynamics of the center of mass.

set to it, but the Robot will beat him at the task!

4. From our common experience with objects about us we early acquire a working knowledge of center of mass: we lift objects by means of single forces applied with due regard to the position of the center of gravity; we set objects down with similar regard if we wish them not to upset. If an object is to be rotated, it is important to have the axis pass through the center of mass; and if a body is tossed into the air, it rotates on a free axis through its center of mass. It is instructive, for example, to find the center of mass of a hammer, to mark it clearly and then to toss the hammer into the air and observe how regular is the rotation about the marked point; or one may drill a small hole through the handle of the hammer at that point and spin it freely with a hand-drill. But it is equally instructive and more entertaining to arrange an object with a shifting center of mass so that it may be thrown into the air and perform variously. A simple disk (Fig. 4) with a movable weight allows this to be done. A 10-in. disk of $\frac{3}{4}$-in. plywood is cut to accom-

modate an iron cylinder $\frac{3}{4}$ in. thick and 3 in. in diameter in a wide slot along one diameter of the disk. End stops are adjusted so that when the iron weight is at A, the center of mass of the system lies at C, the center of the disk; but when the weight is at B, the center of mass is shifted about 2 in. to E. The disk is faced with two $\frac{1}{4}$-in. pieces of smooth pressboard so that the shifting weight is not visible. The center of the disk is marked conspicuously on one side by a white circle, and the eccentric center of mass E is similarly marked on the other side. If, then, the disk is thrown with the first side toward the class, and with its center of mass at C, it rotates normally and looks perfectly "natural." However, if the iron weight is shifted to B and the disk is thrown again, it rotates with a bad wobble, and this wobble can be resolved into a regular motion, much to the surprise of the students, simply by turning the disk so that the other face is toward them. The motion now appears to take place in a regular manner about the eccentric center of mass E. It is possible to throw the disk with either motion at will, for the instructor can easily tell in which position the weight rests when the disk is in his hands; and once tossed, the spinning of the disk keeps the weight at one end of the slot or the other. The weight may, however, change position when the disk is caught again, but the noise of that shift is sufficient to give the instructor warning to make any necessary adjustments before the next throw. A little practice will enable him to operate the disk in a sure but mystifying manner.

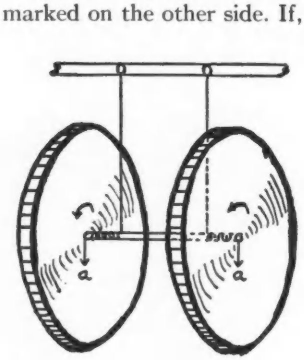

FIG. 5. A "mechanical spider" that descends with a small, constant acceleration.

5. Galileo made his early studies of acceleration by "diluting gravity" with inclined planes or pendulums. Atwood's machine offers another means of obtaining a small, constant acceleration of a system. Still a third method consists in making the accelerating body rotate faster and faster as it acquires higher velocity of translation; that is, in converting a large portion of the potential energy into kinetic energy of rotation rather than of translation. If two disks are mounted on a slender spindle (Fig. 5) and if thread be wound upon each side of the spindle so that the disks, when released, must rotate as they descend, then an acceleration of almost any magnitude smaller than g may be obtained, depending upon the moment of inertia of the disks and the diameter of the spindle. Simple analysis shows that if k is the radius of gyration of the disks and r is the radius of the spindle, the system will descend with an acceleration given by

$$a=\frac{g}{1+(k^2/r^2)}.$$

If, therefore, it is desired to make a disk that will have acceleration of only 1 cm/sec^2, it is necessary to make the ratio k/r equal to 31.4. Such a "mechanical spider" requires more than 14 sec to descend 1 m! Care must be taken to wind the threads on the spindle so that they will pay out at the same rate and so that the spindle will always be horizontal and the load evenly distributed between the two points of support; otherwise, bothersome precessional motions are introduced by gravitational torques and the descending disks perform in an erratic manner. Furthermore, if the spindle is very small, the diameter of the thread may introduce errors, and if the thread is wound in several layers on the spindle, the consequent increase in effective diameter of the spindle may make the initial acceleration too great and hence shorten the calculated time of descent considerably.

6. The rotating stool is excellent for demonstrating Newton's third law of motion as applied to cases of rotation; and there are numerous experiments for illustrating the law in the case of translatory motion. Some laboratories are equipped with reaction carts on which the demonstrator may stand, or across which he may run. The labor and expense of making such carts

are sometimes prohibitive; hence, I should like to describe the simplest way I know to obtain the essential equipment. Take a 4- or 5-ft stiff plank and lay it on two short laboratory rods placed transversely beneath it on the floor. That is all. You step upon such a plank at your peril! If you attempt to walk off along the plank, the plank promptly rolls the other way; if you jump off, it dashes across the room and strikes the wall behind you. However, you may invite a student to ride on the plank and then you can jump farther than before because of the increased mass of the reacting system. This is equivalent to "jumping out of a boat." Your jump may upset the student unless you instruct him in advance to crouch and hold tight to grips provided for the purpose. Numerous variants are readily available; for example, two students mounted on similar planks may have a tug-of-war, or a light student may stand on the floor and a heavy student on the plank, and so forth. I find that students are particularly interested in demonstrations that involve the experimenter's body as part of the "apparatus." Such experiments have the additional advantage of being on a scale sufficiently large to be seen even in big classrooms, an advantage that is shared by far too few of our lecture experiments.

The Motion of a Piston

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THE motion of a piston is treated in but few of the physics textbooks in common use. If we denote the distance of the wrist pin P (Fig. 1) from the center of rotation of the crankshaft O at any instant by x_P, its velocity at that instant by v_P, and its acceleration by a_P, we have

$$x_P = r\cos\theta + (l^2 - r^2\sin^2\theta)^{\frac{1}{2}}, \tag{1}$$

$$v_P = \mathrm{d}x_P/\mathrm{d}t = -\omega r\sin\theta \times[1 + r\cos\theta/(l^2 - r^2\sin^2\theta)^{\frac{1}{2}}], \tag{2}$$

$$a_P = \mathrm{d}v_P/\mathrm{d}t = -\omega^2 r[\cos\theta + r(l^2\cos 2\theta + r^2\sin^4\theta)/(l^2 - r^2\sin^2\theta)^{\frac{3}{2}}], \tag{3}$$

where ω is the angular velocity of the crankshaft (assumed to be constant), l is the length of the connecting rod and r is the radius of the crank arm. Equations (1), (2) and (3) are plotted in Fig. 2 for three values of the ratio r/l; namely, 0, $\frac{1}{2}$ and $\frac{1}{3}$. When r/l approaches zero, the equations reduce to those of simple harmonic motion. Obviously, it makes no difference whether the piston drives the crankshaft, as in an engine, or the shaft drives the piston, as in a pump.

In some applications, it is desirable to know the value of θ for which v_P is a maximum. This maximum value occurs when a_P vanishes. Setting a_P equal to zero, and transposing Eq. (3), we obtain

$$r^4\cos^6\theta + r^2(l^2 - 3r^2)\cos^4\theta - (l^2 - r^2)(l^2 + 3r^2)\cos^2\theta + r^2(l^2 - r^2) = 0. \tag{4}$$

The roots of this cubic equation, while easy to obtain, would be long to write out and awkward to use. However, observing that $\cos^6\theta$ and $\cos^4\theta$ are very small, and therefore considering only the

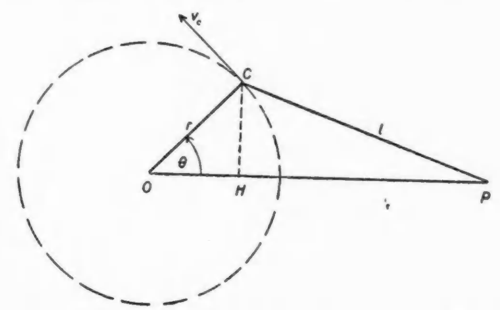

FIG. 1. The point P (the wrist pin) is attached to the point C by the link of length l. The point H executes simple harmonic motion by always remaining beneath (or above) C, which moves with constant speed v_c in a circular path about the center O.

last two terms, we obtain the approximation,

$$\cos^2\theta = r^2/(l^2 + 3r^2), \tag{5}$$

which agrees with the exact solution to within a

few minutes of arc over the useful range of values of r/l. (See Fig. 3.) The graph of the exact relation may easily be plotted by solving Eq. (4) for $(r/l)^2$, thus obtaining

$$(r/l)^2=[\sin\theta\pm(\sin^2\theta-4\cos^2\theta)^{\frac{1}{2}}]/2\sin^3\theta.$$

For those who have not yet studied the calculus, Eqs. (2) and (3) can be derived by simple geometric means as follows.

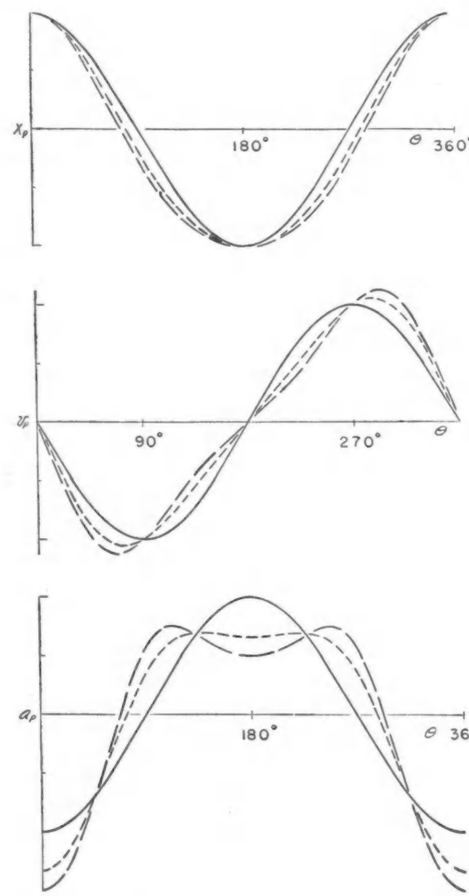

FIG. 2. *Top*, the displacement of the piston as a function of the angle of rotation of the crankshaft; *middle*, the velocity of the piston; *bottom*, the acceleration of the piston. *Solid line*, $r/l=0$ (simple harmonic motion); *short dashes*, $r/l=\frac{1}{3}$; *long dashes*, $r/l=\frac{1}{2}$. The apparent intersections of the acceleration curves at approximately 50° and at 137° are only apparent; the common intersections of the velocity curves at 90° and at 270° are real.

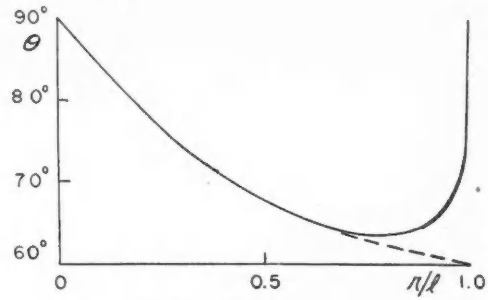

FIG. 3. The position of the crankshaft for which the velocity of the piston is a maximum. The solid line is the graph of the exact relation, Eq. (4); the dotted line is the result given by the approximation, Eq. (5).

Consider the particle C (Fig. 1) to be moving in the circle of radius r with constant speed v_C and with centripetal acceleration a_C, where

$$v_C=\omega r,\quad a_C=-\omega^2 r. \tag{6}$$

Consider next the particle H, which is executing simple harmonic motion. Its position x_H, its velocity v_H and its acceleration a_H are, at any instant, the horizontal components of r, v_C and a_C at that instant; that is,

$$\begin{aligned} x_H&=r\cos\theta,\\ v_H&=-v_C\sin\theta=-\omega r\sin\theta,\\ a_H&=a_C\cos\theta=-\omega^2 r\cos\theta. \end{aligned} \tag{7}$$

Now, let us study the particle P, which is connected to the particle C by the connecting link of length l. If we denote the height from H to C by m, and the distance from H to P by n, we have

$$\begin{aligned} m&=r\sin\theta,\\ n&=(l^2-m^2)^{\frac{1}{2}}=(l^2-r^2\sin^2\theta)^{\frac{1}{2}}; \end{aligned}$$

and the position of the piston P is given by

$$x_P=x_H+n=r\cos\theta+(l^2-r^2\sin^2\theta)^{\frac{1}{2}}. \tag{1}$$

The velocity of P with respect to O is the sum of its velocity with respect to H and the velocity of H with respect to O. Now, it is easy to show that the velocity of P with respect to H is given by

$$v_n=-(m/n)v_m, \tag{8}$$

where v_m is the vertical component of v_C; that is, $v_m=\omega r\cos\theta$, so that

$$v_n=-\omega r^2\sin\theta\cos\theta/(l^2-r^2\sin^2\theta)^{\frac{1}{2}}.$$

Thus

$$v_P=v_H+v_n=-\omega r\sin\theta[1+r\cos\theta/(l^2-r^2\sin^2\theta)^{\frac{1}{2}}]. \tag{2}$$

Similarly, the acceleration of P with respect to O is the sum of its acceleration with respect to H and the acceleration of H with respect to O. The acceleration with respect to H is itself composed of two parts: one due to the rotation of the link; the other, to the vertical component of a_C.

The part due to the rotation of the link is associated with the fact that the fraction m/n in Eq. (8) is constantly

changing, so that, even if v_m were constant, v_n would be constantly changing; that is, the particle P would be accelerated toward H. As the link goes through its mid-position ($m=0$, $n=l$), this acceleration is simply the centripetal acceleration v_m^2/n. In any other position, this acceleration is $(l/n)^2 v_m^2/n$.

The part due to the vertical component of a_C—that is, the part due to the rate of change of v_m—is given by an expression exactly similar to Eq. (8).

Adding all these terms in the expression for the acceleration of the piston, we have

$$a_P = a_H - (l/n)^2 v_m^2/n - (m/n)a_C \sin\theta,$$

which can easily be converted into Eq. (3).

A Novel Method of Contact Photography

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Kansas State College, Manhattan, Kansas

A PHOTOGRAPHIC effect that had all the aspects of a paradox was observed in our laboratory several years ago. Because of its simplicity, the effect probably has been observed before, although a search of literature has failed to reveal any record of it. The interpretation of the effect was at first quite puzzling but upon investigation was found to be rather simple. Because of the varied applications, the effect should be of particular interest to teachers of photography.

The effect is produced by the arrangement of photographic film, opaque object and light source shown schematically in Fig. 1. Parallel light falls on the back side of the opaque object to be photographed and also on a portion of the uncovered film. The film when developed reveals, in addition to the blackening of the protruding film, an image of the surface AB of the opaque object. Thus one obtains a contact photograph of an opaque object by directing the illumination on the back side of the object. There can be no doubt as to the opaqueness; objects made from $\frac{1}{4}$-in. brass plates have been used. The image formed is a negative image and in that respect is like the film one would obtain if the surface AB were photographed in the ordinary way.

After photographing many objects in this manner, we were led to a classification of images into those that are reproductions of the contours of the surface AB and those that depend upon the reflecting powers of the various parts of the surface. In Fig. 2 are shown "contour" images of several objects—wooden ink bottle tops, a key and a coin. The figure is a contact print made from the original negative. Images of the "reflection" type are shown in Fig. 3. The opaque objects which were reproduced include photographs and black printing on white paper. To assure opacity, the object was covered by metal or wood. The negatives for Figs. 2 and 3 were made from Eastman Par Speed Portrait film which had been exposed for 20 sec with an illumination of about 5 ft-ca from a Mazda lamp. In our experiments the opaque objects have at different times been made of metal, paper and wood.

Eastman Panchromatic Super-Sensitive film was also employed successfully, but the slower Par Speed Portrait film gave the better image. Photographic plates as well as photographic paper also give images, although the best results were obtained with film.

The light sources which were used included a mercury arc, a common tungsten filament light bulb and daylight. The image formation seemed quite independent of the light source as long as

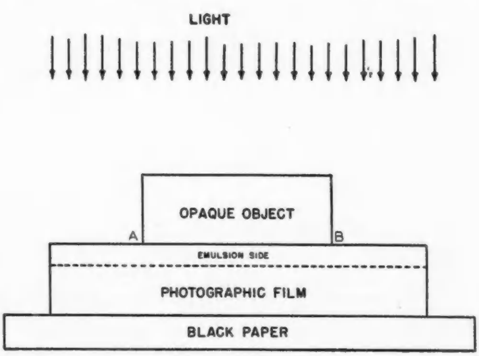

FIG. 1. Arrangement of materials.

the spectral distribution of the latter included the visible range of the spectrum. When ultraviolet light alone was used, the effect failed to appear.

When this method of obtaining contact images was first observed, a number of explanations were offered. First of all, it was suggested that the image was formed by an electric process. It was assumed that a charge accumulated on the object through photoelectric action and subsequently discharged to the film. This explanation was shown to be incorrect by the simple expedient of grounding the object and film. Moreover, the fact that the effect occurred for insulators as well as conductors made any other electric theory unacceptable. Since it is known that pressure or contact with a film will form an image, experiments were made without the usual illumination. The results were negative, thus showing that

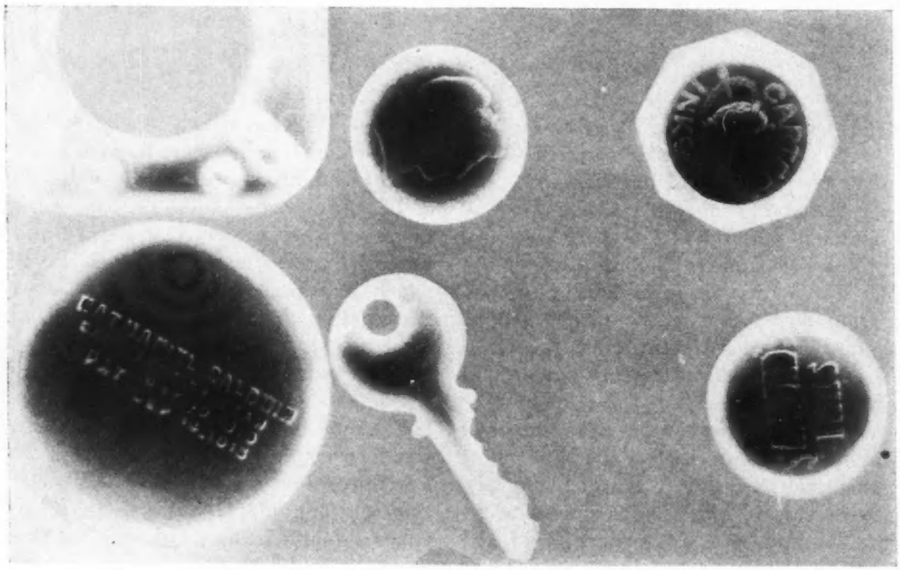

FIG. 2 (Above). Examples of "contour" images.

FIG. 3 (Left). Examples of "reflection" images.

pressure and contact by themselves play no part in the image formation.

It soon became evident that the image production was the direct result of an illumination of the surface AB which is in contact with the film. To determine whether the light passed between the opaque object and the emulsion or entered and passed through the emulsion, the opaque object was taped securely to the film on all four sides, as shown in Fig. 4. Reproductions could not be obtained using this arrangement.

It is apparent, therefore, that the "reflection" images are formed by light that enters the finite air gap between the opaque object and the film. This diffused light is better reflected by a white area so that the developed film acquires a correspondingly high optical density. On the other hand, the "contour" images are formed by the light reflected from those portions of the surface that are close to or in contact with the film. These yield dense portions in the developed film. Light entering recessions in the surface is

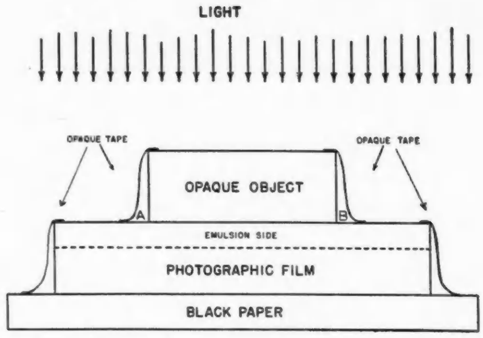

FIG. 4. An image cannot be obtained with this arrangement.

trapped; consequently, the film when developed reveals a relatively small optical density in regions corresponding to these recessions.

In the case of ultraviolet light, distinct images are not found because of the very different reflecting properties of the gelatin and objects for the short wave-lengths.

Elmer Samuel Imes, 1883–1941

AFTER a long, courageous fight Elmer Samuel Imes succumbed in Memorial Hospital, New York City, on September 11, 1941. With his passing future generations of physics students have lost the privilege of studying under a truly masterful teacher; his colleagues, an esteemed counsellor; and his family and friends, a devoted companion.

Born in Memphis, Tennessee, on October 12, 1883, Doctor Imes received the A.B. degree with highest honors in 1903 at Fisk University. From 1903 to 1915 he taught physics in American Missionary Association schools and at his alma mater, earning his M.A. degree from the latter institution in 1910. His final period of graduate studies began in 1915 at the University of Michigan, where he won a University Fellowship for the years 1916–1918, as well as membership in the Society of Sigma Xi.

His doctoral dissertation in 1918, "Measurements on the near infra-red absorption of some diatomic gases," first showed the existence of rotational fine structure in the absorption spectra of diatomic molecules, which in turn yielded further clues as to the structure and mechanical properties of the hydrogen halide molecules. This valuable and painstaking work won for him international recognition among fellow physicists. Reference has constantly been made to it in the literature. Often during the writer's five years service as instructor under him, Doctor Imes, in his typically modest fashion, depreciated some proffered commendation by remarking that had he known even more physics at the time he might also have predicted the isotopy of chlorine from his 3.46μ HCl band.

Doctor Imes' exceptional research aptitude kept him employed between 1919 and 1929 as research and consulting engineer and physicist with the Burrows Magnetic Equipment Corporation, the Federated Engineers Development Corporation and the E. A. Everett Company. The skill which he possessed in his special fields of radiation and magnetic problems is revealed in his development of numerous patented devices. In 1929 he returned to Fisk University as research professor and head of the department of physics. In this capacity he built up, until the day of his death, a program of training for the students that has proved enviable among similar undergraduate institutions. This activity was continuously supplemented by a consulting relationship with Autoxygen, Incorporated, of New York City, and by membership in leading professional societies. The genius of the man for inspiring his students and his associates will cause his memory to linger long in the hearts of many.

ALFRED E. MARTIN

A Mechanical Device for Exhibiting the Properties of a Thin Lens

Ira M. Freeman
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A FAMILIAR nomograph for locating pairs of conjugate foci of a converging lens is shown in Fig. 1. Any straight line drawn through

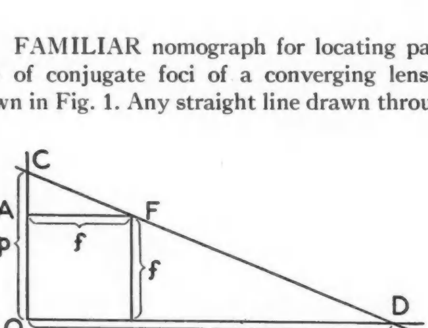

FIG. 1. Simple alinement chart for conjugate points of a converging lens.

the point F will cut off segments p and q on the two axes satisfying the simple thin lens equation. This can be seen by comparing the similar triangles CFA and FDB; the proportionality of corresponding sides gives

$$f/(p-f)=(q-f)/f, \tag{1}$$

whence

$$1/p+1/q=1/f. \tag{2}$$

It seemed desirable to attempt to design a nomograph that would locate the two conjugate points on the same straight line, as are the object-point and the corresponding image-point in the actual optical case. A further aim would be to extend the representation to include diverging lenses. For purposes of elementary instruction such a nomograph would enable the student to visualize in a continuous way exactly what happens to the image as the object is moved relative to a lens. Even in an actual laboratory experiment, the continuity and direction of the changes in position are not always impressed upon the student, since he must first move the source, then move the screen back and forth until sharp focus is attained. If he is accustomed to the use of a camera, he will probably recall that the lens must be racked out in order to form a sharp image of nearer objects, but a graphic appreciation of many features of image formation will still be lacking. Moreover, the case of virtual images may not come within his conscious experience at all.

It was found possible to devise a simple mechanical arrangement for exhibiting many aspects of image formation. In Fig. 2, the two lines AB and CD are fixed at right angles so that they form a cross. This cross rests on two fixed pegs E and F, and the cross may be rotated either clockwise or counterclockwise as it slides on the pegs. Dimensions are given in the diagram in terms of f, the focal length. Then it follows that the segments p and q cut off on the line MN satisfy the relation $1/p+1/q=1/f$ for the conjugate distances of a thin converging lens immersed in a homogeneous medium and forming a real image; for, as before, by considering similar triangles such as EGH and LKF, Eq. (1) is obtained. The foregoing representation illustrates several important features of real-image formation: the slow approach of the image to the focal point on the opposite side of the lens as the object recedes to infinity; the symmetric position, in which the object-image separation is a minimum; the interchangeability of object and image in every instance.

The relations for the virtual images formed by a diverging lens are represented, again with geometric exactness, by the intersections of the upper arms of the cross with the line RS. The object-point and image-point will of course now fall on the same side of the lens, and the distances satisfy the relation $1/p-1/q=-1/f$. This follows readily from the fact that, in the triangles TVF and EWY, $(p+f)/f=f/(f-q)$. Here again the

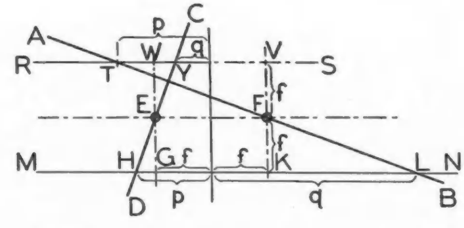

FIG. 2. Generalized nomograph for converging and diverging lenses.

physical features of the image formation are faithfully represented: As the object-point moves in from infinity the image-point moves toward the lens from the left-hand focal point, and the two approach each other as they close down to the lens itself.

In order to provide a visual demonstration for a class, the aforementioned design has been incorporated in a device that can be shown by projection in a lantern. It consists of a slotted disk made of transparent, colored sheet plastic material which turns on pins fixed in a suitably slotted rectangle of sheet brass (Fig. 3). The assembly is projected as an ordinary lantern slide, the position of the disk being controlled by the operator. On the screen the axes and the profile of the lens appear in color, while the object-point and image-point are white (Fig. 4). For simplicity, the axis of the converging lens is carried inward from each side only as far as the focal point, since no real image ever approaches closer to the lens. Small nicks filed in the brass plate at multiples of the distance f are convenient for scaling off distances. While the greatest value of the device is in making vivid the general lens relations, actual measurements can be made on the projected image, using a meter stick, and

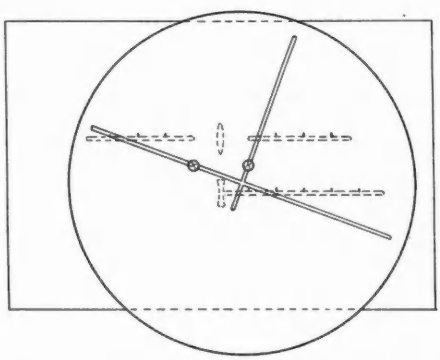

FIG. 3. Design of the nomograph for use in a projection lantern. The position shown is that of the device as seen by the operator.

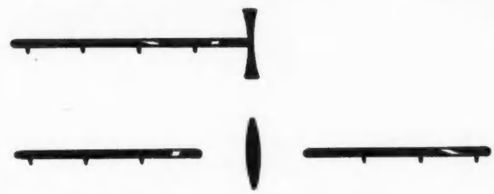

FIG. 4. Appearance of the projected image.

thus approximate solutions to lens problems can be obtained by a nomographic method.

It is interesting to notice that the finite width of the object and image spots, which at first sight seems a defect of the device, actually serves to depict still another feature of the image formation. In Fig. 5, let w be the width of the slots in

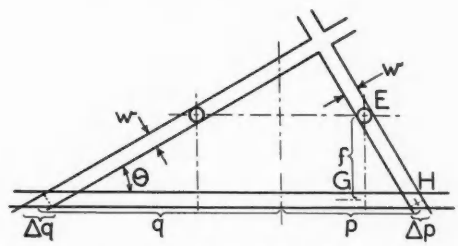

FIG. 5. Geometric significance of the finite width of the object and image spots.

the disk, and let the widths of the object and image spots, measured in each case along the lens axis, be Δp and Δq, respectively. Then, from the small triangles, $\Delta q = w \csc\theta$ and $\Delta p = w \sec\theta$. Thus $|\Delta q/\Delta p| = \csc\theta/\sec\theta = \cot\theta$. In the triangle EGH, $\cot\theta = f/(p-f)$ and, from the lens equation, this is equal to q/p. Hence

$$|\Delta q/\Delta p| = q/p = m_t, \tag{3}$$

so that, for any pair of positions, the ratio of the widths of the image and object spots is equal to the transverse magnification.

The device is to be made available for classroom use by a manufacturer of scientific apparatus.

My own way is to write and rewrite things, until by some sort of instinctive process they acquire the condensation and symmetry which satisfies me. And I really could not say how my original drafts are improved until they somehow improve themselves.

—THOMAS HENRY HUXLEY.

The Double Torsion Pendulum in a Liquid

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University of Cincinnati, Cincinnati, Ohio

IT is believed that the usual course in analytical dynamics would be greatly improved, from the point of view of student interest and clear understanding, if more specific demonstrations of the topics treated were presented.

The double torsion pendulum in a liquid affords an excellent concrete example of oscillation problems beyond the elementary type, and has the added advantage of showing very clearly the importance of "virtual" moment of inertia and mass in the treatment of any problem in which all or part of the system is moving in a liquid. It is the purpose of this article to describe such a pendulum and to give typical data comparing experimentally determined values of the fundamental periods of oscillation, both in air and in water, with computed values.

Construction details are shown in Fig. 1. A piano wire, 0.673 mm in diameter, is stretched tightly between opposite sides of a rectangular wooden frame. Two crossarms, AA and BB, each consisting of a slender brass rod with a lead disk attached to either end, are rigidly fastened to the wire as indicated. The lead disks have a thickness of 3.5 mm and the brass rods are each 3.92 mm in diameter. All other dimensions are shown in Fig. 1. Obviously these dimensions may be varied to suit particular needs or materials at hand.

Since this is a problem involving two degrees of freedom, there are two fundamental modes of oscillation. One of these is represented when the crossarms are moving together in phase and the other when their motion is exactly out of phase. With a little practice, it is quite easy to excite either mode of motion alone. Hence the fundamental periods both in air and with the frame submerged in water may be obtained experimentally merely by timing a large number of oscillations with a stop watch.

In order to compute the periods it is necessary to know (a) the torsional constant of each section of the wire, (b) the moments of inertia of the crossarms AA and BB in air and (c) their moments of inertia in water. Each of these quantities is determined experimentally by making use of a simple torsion pendulum similar to the one shown in Fig. 1 but having only one crossarm. When the free period T of oscillation of this pendulum in air is known, the torsional constant k of the wire can be obtained from the usual relation,

$$T=2\pi(I/k)^{\frac{1}{2}}, \tag{1}$$

where I is the computed moment of inertia of a long slender rod used as a crossarm. To determine α, the torsional constant per unit length of the wire, use is made of the relation,

$$k=\alpha(1/l_1+1/l_2), \tag{2}$$

where l_1 and l_2 represent the lengths of the wire above and below the crossarm, respectively. The numerical value of α for our apparatus was found to be 1.51×10^6 dyne cm^2/rad. Hence the torsional constant for each section of the double pendulum is given by α/L_1, α/L_2 and α/L_3, respectively, where L_1, L_2 and L_3 represent the lengths of the wire indicated in Fig. 1.

TABLE I. Comparison of experimental and computed values of the fundamental periods.

Period (sec)	In air Experimental value	In air Computed value	In water Experimental value	In water Computed value
T_1	1.18	1.17	1.45	1.43
T_2	1.98	1.93	2.36	2.33

The slender rod of the simple torsion pendulum is now replaced by the arm AA from the double pendulum and the periods of oscillation both in air and in water are determined. Applying Eq. (1) again, this time with k known, the moment of inertia of the arm and its effective moment of inertia—real plus virtual—in water are computed. A repetition of this procedure gives the corresponding values for the arm BB. One can, of course, compute the moments of inertia of these arms from the known masses and dimensions. Likewise, the effective values in water can be computed from the known masses, dimen-

sions and virtual masses.[1] However, the accuracy of directly determined experimental values is probably greater.

A brief outline of the way in which the fundamental periods of the double pendulum are computed is given below. The Lagrangian function in generalized coordinates,

$$L=E_k-E_p=\tfrac{1}{2}\sum_{ij}^{n} a_{ij}\dot{q}_i\dot{q}_j-\tfrac{1}{2}\sum_{ij}^{n} c_{ij}q_iq_j,$$

becomes, for the double pendulum in air,

$$L=\tfrac{1}{2}(I_1\dot{\theta}_1^2+I_2\dot{\theta}_2^2)-\frac{1}{2}\left[\frac{\alpha}{L_1}\theta_1^2+\frac{\alpha}{L_2}(\theta_1-\theta_2)^2+\frac{\alpha}{L_3}\theta_2^2\right], \quad (3)$$

where I_1 and θ_1 represent, respectively, the moment of inertia and angular displacement from equilibrium of arm AA, and I_2 and θ_2 have similar meanings for BB. Applying the Lagrangian equation,

$$\frac{d}{dt}\left(\frac{\partial L}{\partial \dot{q}_r}\right)-\frac{\partial L}{\partial q_r}=0,$$

to Eq. (3), we obtain the two equations of motion,

$$a_{11}\ddot{\theta}_1+c_{11}\theta_1+c_{12}\theta_2=0, \quad (4)$$

$$a_{22}\ddot{\theta}_2+c_{21}\theta_1+c_{22}\theta_2=0, \quad (5)$$

where

$a_{11}=I_1=0.701\times10^4$ g cm^2,
$a_{22}=I_2=1.085\times10^4$ g cm^2,
$c_{11}=\alpha(1/L_1+1/L_2)=1.760\times10^5$ dyne cm/rad,
$c_{12}=c_{21}=-\alpha/L_2=0.641\times10^5$ dyne cm/rad,
$c_{22}=\alpha(1/L_2+1/L_3)=1.557\times10^5$ dyne cm/rad.

From Eqs. (4) and (5) the fundamental determinant of the system can be written down at once as

$$\begin{vmatrix} a_{11}\omega^2-c_{11} & -c_{12} \\ -c_{21} & a_{22}\omega^2-c_{22} \end{vmatrix}=0. \quad (6)$$

The two natural periods of motion are obtained by inserting the two values of ω that satisfy Eq. (6) in the relations $T_1=2\pi/\omega_1$ and $T_2=2\pi/\omega_2$.

[1] Yee-Tak Yu, "Virtual masses and moments of inertia of disks and cylinders in various liquids," J. App. Phys. **13**, 66–69 (1942).

To obtain the natural periods in water an exactly similar procedure is followed except that I_1 and I_2 are replaced by the "effective" values, which were $I'_1=1.056\times10^4$ g cm^2 and $I'_2=1.576\times10^4$ g cm^2.

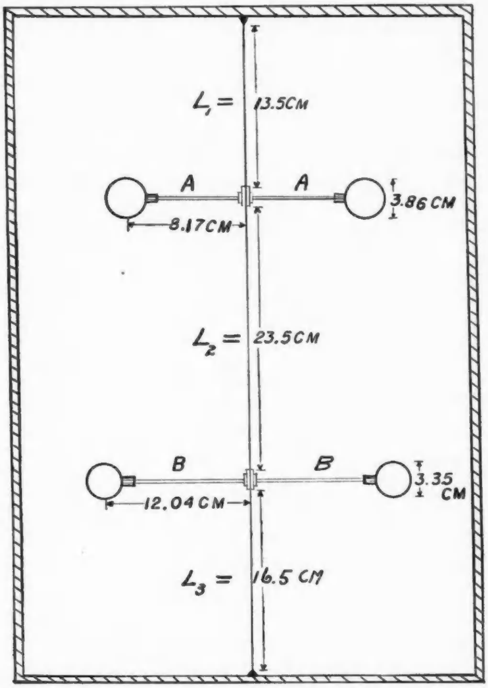

FIG. 1. A double torsion pendulum for experiments in air or in a liquid.

In treating the double pendulum, no account of damping is taken since previous experience with a single torsion pendulum has shown that its effect on the fundamental periods of this particular apparatus is very small.

A comparison of experimental and computed values of the fundamental periods in air and in water is afforded by Table I, where T_1 and T_2 refer, respectively, to the periods when the motion of the two arms is out of phase and in phase. The agreement between experimental and computed values is quite close. It seems certain that a class demonstration of such a pendulum and of the results that can be obtained with it will not fail to promote interest in the subject at hand and confidence in the methods employed.

Physics Teacher Rating in the Summer Engineering Defense Training Program

C. J. Lapp, *State University of Iowa, Iowa City, Iowa*

AND

Marsh W. White, *The Pennsylvania State College, State College, Pennsylvania*

During the summer of 1941, the Pennsylvania State College operated, through its Extension Division, an EDT program approved by the United States Office of Education. In this extensive program[1] college physics was taught eight hours per week for ten weeks. This program of instruction carried out by 127 physicists involved the largest number of physics teachers ever operating as a single teaching unit. The actual teaching was done by 112 teachers at 96 centers and was supervised and administered by a staff of 15.

The teachers were well trained and came from highly diversified backgrounds, holding permanent positions in 29 states and the District of Columbia. About 40 were responsible for their physics "departments," including a number of one-man departments. The baccalaureate degrees, which were held by all of the teachers, were conferred by 93 different colleges and universities, four being the largest number conferred by any one institution. One hundred eleven held master's degrees from 57 different institutions. The institutions conferring 5 or more of these master's degrees were: University of Michigan, 9; University of Illinois, 8; Pennsylvania State College, 8; State University of Iowa, 5; Ohio State University, 5; University of Pennsylvania, 5; University of Wisconsin, 5. The average age of the teachers was 35.8 years, 5 being less than 24.5 years and 11 being more than 49.5 years. Tables I to IV present additional evidence of the high caliber of the physics staff.

The whole physics program was directed by one of the present authors, assisted by six field supervisors, all experienced in the teaching of college physics. After each teacher's work had been observed several times, the field supervisor carefully listed the teachers in his groups in order of their excellence, as measured subjectively by the evidence he had collected. Each field

Table I. Present professional position.

College	
Graduate assistants, fellows, etc.	15
Instructors	28
Assistant professors	30
Associate professors	16
Professors	29
Research	2
Secondary School	7

Table II. Highest degrees held.

Bachelor of Arts and Bachelor of Science	8
Master of Arts and Master of Science	35
Doctor of Philosophy	80
Special Degrees (Ph.M., B.E.E., D.Sc., M.S.E.)	4

Table III. Average number of years of teaching experience.

Of 105 college teachers in college field	11.31
Of 67 Ph.D.'s since degree was granted	7.30
Of 6 secondary school teachers in secondary school field	6.34
Of 105 college teachers in secondary school field	0.89

Table IV. Institution granting degree of doctor of philosophy to staff.

Boston University	1
Catholic University	1
Columbia University	3
Cornell University	7
Duke University	2
Harvard University	2
Johns Hopkins University	3
Massachusetts Institute of Technology	3
New York University	1
Northwestern University	2
Ohio State University	4
Pennsylvania State College	6
Princeton University	1
University of Chicago	2
University of Illinois	7
University of Indiana	3
University of Iowa	5
University of Kansas	1
University of Michigan	11
University of Minnesota	1
University of Missouri	2
University of North Carolina	1
University of Pennsylvania	2
University of Texas	2
University of Virginia	1
University of Wisconsin	2
Yale University	4
Total	80

[1] M. W. White, "The 1941 summer engineering defense training program of the Pennsylvania State College," Am. J. Phys. 9, 361–367 (1941).

supervisor was also asked to indicate those teachers who, in his judgment, were equal to the best 15 percent of all the college physics teachers about whom he had accurate information. These were rated A. Appropriate letter ratings, B, C, and D, were assigned to the others. This was called the *supervisors' subjective rating*.

Two weeks later the field supervisors were given a teacher rating blank on which each teacher was rated. After this rating was evaluated numerically, letter grades were assigned. This was called the *supervisors' objective rating*. The average of these subjective and objective ratings was called the *supervisor rating*. The supervisor rating resulted in 16 percent A, 43 percent B, 32 percent C and 9 percent D. For some purposes these letter ratings were converted to numerical values: $D- = 1$, $D = 2$, $D+ = 3$, and so on to $A = 11$.

The form on which the field supervisors made their objective rating is shown in Table V. The person making the rating checked each item at the proper point on the scale. Numerical values were assigned by means of the scale at the top of the form, and these values were totaled for each part. The total value for Part I was halved because this part contains twice as many items as each of the other parts. Letter grades were

TABLE V. Teacher rating blank.

	1	2	3	4	5
Part I. *Vital things a teacher brings to class and how well they are used.*					
(1) Understanding of physics taught	Deep comprehension		Adequate		Hazy in spots
(2) Daily preparation	Careful		Casual		Careless
(3) Energy	Plenty of energy used to advantage		Nonproductive display of energy		Low in energy
(4) Creativeness in attacking whole problem	Ingenious and sound		Average		Lacking in imagination
(5) Consciousness of objective for a specific class period	Teaching aimed at clear objectives		Teaching well directed		Just taught
(6) Variation of approach	Nice change of pace; good timing in various teaching approaches		Average college teacher		A plodder; methods standard
Part II. *Partial measure of a teacher's attitude.*					
(7) Cooperation	Worked well with everyone		Average		Lone wolf
(8) Attitude toward summer job	Willing to make personal sacrifices to render program successful		Gives about value received		An opportunist
(9) Attitude toward students	Friendly but respected		Aloof		Fraternized to teacher's disadvantage
Part III. *Class response, a partial measure of level at which group works.*					
(10) Discipline	Good		Average		Class poor
(11) Ability to get a class to work	Class works willingly and hard		Average		Class relaxes and relies on instructor
(12) Mental contact between class and instructor	Works at "meeting of the minds"		Average		Students and teacher never quite get together

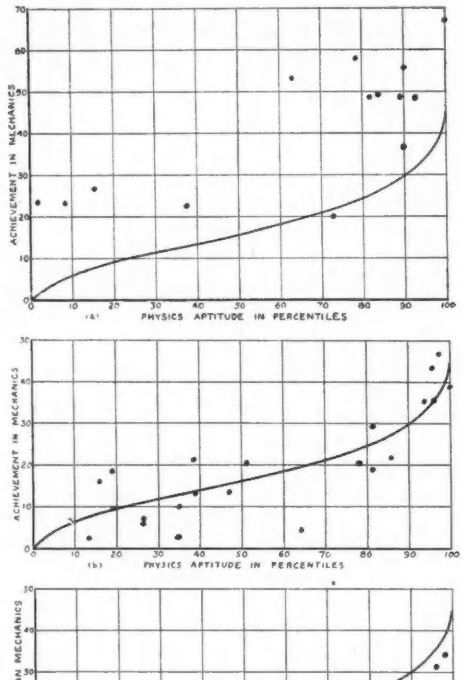

FIG. 1. The curve shows the average achievements for each ability level, while each dot represents the achievement of a particular student. The diagrams reproduced here are for the three classes that showed (a) the highest, (b) an average and (c) the lowest achievements among the 112 classes.

assigned according to the following scale: *A*, 3; *B*, 4, 5, 6; *C*, 7, 8, 9; *D*, 10 to 14. The final rating was the average for the three parts. This blank might be found useful in rating teachers where several are teaching the same course. The correlation between the two types of supervisors' ratings was .70.

At the opening of each center a battery of tests was given to each student. The tests giving valid physics aptitudes were found to be the *Cooperative physics test for college students*, Mechanics 1936 A, used as a pretest, *Iowa physics aptitude test*, Form M, 1941, Moore's *Arithmetical reasoning*, Bennett's *Mechanical comprehension*, Otis' *Self-administering test of mental ability*, Form A, and Strong's *Vocational interest test* scored for sales, purchasing agent and engineering. By statistical methods these test scores were given optimum weightings, and an aptitude score was established for each student. Thus the mean aptitude for every class was the average of the sum of the aptitudes for the students in that class.

The achievement measure was the sum of the scores made at the end of the work in mechanics on the *Cooperative physics test for college students*, Mechanics, 1936 B, and two examinations consisting of ten problems each, the problems of which were selected to have three grades of difficulty. Complete data were obtained for 1845 students. These were divided into percentiles, and the mean final achievement was found for each percentile.

By plotting the mean percentile scores as ordinates and the percentiles as abscissas, a curve was obtained that shows the mean achievement for every level of ability. This curve was reproduced on cross-section paper. On such a sheet a dot was placed for each student so that its ordinate represented his achievement and the abscissa his aptitude. A sheet was prepared for each class, having on it a dot for every student. This dot diagram is in reality a measure of a situation—the teacher and the center at which he taught—because it shows at a glance the achievement of this particular class as compared with that of all other students in the entire program. Moreover, this comparison is fair in that account is taken of every student and of every class.

Figure 1(a) is the diagram for the class[2] that showed the highest achievement among the 112 classes. The class as a whole had a fine aptitude rating, the 70th percentile, although there were 3 other classes having higher ratings. If each member of this class had achieved the same amount as the average of all other students of the same ability, each dot would have been on the curve and the class achievement as a group would have been numerically 24.2. Instead, its achievement was 41.4, not only the highest in the program, but a gain of 71 percent more than all other students of equal ability. Furthermore,

[2] *Class* here means all of the students taught by one teacher.

the students in this group varied widely in ability and yet all showed high achievement in comparison with that expected from their aptitudes.

Figure 1(b) is a diagram for an average class, while Fig. 1(c) is for the class that achieved the least in comparison to its aptitude of all the classes in the program. The latter result is particularly tragic when it is noted that this class had the second highest aptitude in the program and was taught in one of the best equipped centers. Lowest in achievement of all the group, it stood 16 percentiles higher in aptitude than the class that finished first.

One of the authors has described[1] a research program on physics teaching in connection with the summer work, the results of which will soon be published. In this experimental program the 62 teachers whose centers opened before June 17 served as a control group and taught in the conventional manner, while the 50 teachers whose centers opened after that date constituted the experimental group and employed special teaching methods.[1] When the supervisors' teacher ratings for the two groups were compared numerically it was found, as would be expected, that the teaching excellence of the two groups was almost identical, the small increment of difference being in favor of the control group.

The data from which the dot diagrams were made have been treated numerically and the classes listed in the order of their achievement when corrected for aptitude. The program resulted in an average net gain for the experimental group. When further corrections were made for the added achievement of the classes in the experimental group owing to aid received, which resulted in an increment of student achievement not rightly attributed to the teacher, a final teacher list, called the *research supervisor's rating*, was made on a basis of numerical rating of class achievement. These ratings were converted to letter grades by using the same percentage of *A*'s, *B*'s, *C*'s and *D*'s as were assigned by the field supervisors. The correlation between the field supervisors' rating and the research supervisor's rating is not as high as the correlation between the two ratings made by the field supervisors.

It is believed that the methods of teacher rating described in this paper would be useful for evaluating relative teaching achievement in institutions where many teachers participate in the same courses. A particular application would be the rating of graduate assistants in a large college or university.

The authors are deeply appreciative of the expert statistical work directed by Mr. Charles Griffin, which made possible the dot diagram and the final ratings of the research supervisor.

Readings on Interconnections of Science and Society

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WALDEMAR Kaempffert has recently said: "It is slowly dawning on scientists that science belongs not to them alone. Such books as Hogben's *Science for the citizen* show that a few of the younger English professors realize that science is a social force, like religion or art, that it must be elucidated as such, that it is not enough to explain physical, chemical and biological principles."

The following conspectus of items selected from the publications of the last three years is indeed testimony to the fact that scientists, American as well as English, are thinking in this direction, though their instruction may not be perfectly shaped to this ideal, and though it may not be generally accepted as the chief end even of the liberal arts course. By intention the expression of opinion by chemists and biologists has been placed alongside that of physicists. Articles that have appeared in the AMERICAN JOURNAL OF PHYSICS are not included, since they are listed in the annual indexes of the Journal.

Books and Pamphlets

Bernal, J. D. *The social function of science* (Macmillan, 1939; 482 p.). Its major thesis is that, as science has relieved man of his helplessness before natural phenomena, it can and must find ways to mitigate his helplessness

before man-made disasters. Alphabetically and in importance first on the list.

Bragg, Sir W. *Science and faith* (Oxford, 1941; 24 p.). Riddell lecture, Durham University.

Bridgman, P. W. *The intelligent individual and society* (Macmillan, 1938; 305 p.). An intimate account of how a notable physicist, one of whose specialties is logic, applies his scientific attitudes to the universal problems of living.

Compton, K. T. *The social implication of scientific discovery* (Am. Phil. Soc., 1938; 33 p.). Jayne memorial lecture.

Crowther, J. G. *The Social relations of science* (Macmillan, 1941; 665 p.). How science came into existence, the conditions that stimulate it, and what may be done to create an effective social policy for the future; from an angle a little to the left of the usual viewpoint.

Findlay, A. *Science and the community* (New Zealand Council for Educational Research, Studies No. 4. Oxford, 1939; 19 p.).

Gregory, Sir R. *Cultural aspects of science* (Carnegie Inst. Washington, 1938; 56 p.). Elihu Root lecture on the influence of science.

Haldane, J. B. S. *Science and everyday life* (Lawrence and Wishart, 1939; 284 p.). A collection of his contributions to the *Daily worker;* an interesting demonstration of how one scientist endeavors to help science really function in society at large.

Harrison, G. R. *Atoms in action: the world of creative physics* (Morrow, 1941; 401 p.). A glamorous account of the contributions of pure physics in recent years to the happy possibilities of existence. Concludes with a bibliography of some 20 well-chosen titles among earlier books.

Hogben, L. T. *Science for the citizen* (Knopf, 1938; 1082 p.). Aims to place the science which it expounds in its social setting.

National Research Council. *Research, a national resource. Part 2, Industrial research* (Govt. Print. Off., 1941; 369 p.). A report to the National Resources Planning Board that covers general questions of historical development, present organization, opportunities for careers and an analysis of the problems of each major field of endeavor. A superior bibliography accompanies each section.

Richardson, E. G. *Physical science in art and in industry* (English Universities Press, 1940; 293 p.). "A cross section of twentieth century activity . . . against its historical background."

Thornton, J. E., comp. *Science and social change* (Brookings Inst., 1939; 571 p.). A collection of essays and lectures from a variety of viewpoints, and from the day of Tyndall to the present, but preponderantly from the 1930's.

Ward, H., ed. *New worlds in science* (McBride, 1941; 670 p.). An anthology consisting of entire chapters from 32 books of the last ten years by as many authors, in two sections entitled "Designs for living" and "Conquest of energy." A veritable *multum in parvo.*

Wendt, G. L. *Science for the world of tomorrow* (Norton, 1939; 316 p.). An enthusiastic brief for the necessity of continuing research in science and engineering. The chapter on "Science and leisure" is particularly to be recommended.

Editorials, News Items and Articles

Editorials

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"Science and the war," "Discovery and invention in wartime," *Nature* **144**, 953, 954–955 (1939).

"Men of science and the war," *Nature* **146**, 107–108 (1940).

"Challenge of science," *Nature* **146**, 175–177 (1940).

"Science and the national war effort," *Nature* **146**, 469–470 (1940).

"What is a physicist?" *Nature* **147**, 617 (1941).

"Cultural significance of the scientific method," *Nature* **146**, 815–818 (1940); comments by M. Polanyi and C. H. Waddington, *ibid.* **147**, 119, and **147**, 206 (1941).

"Science, politics and government," *Nature* **147**, 275–276 (1941).

"Science in modern life," *Nature* **147**, 551–553 (1941).

"Le coq d'or," *Nature* **147**, 785–786 (1941); reprinted, Rev. Sci. Inst. **13**, 199 (1942); see also *J. App. Phys.* **12**, 511 (1941).

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"American defense and physicists," *J. App. Phys.* **11**, 451, 509, 567 (1940); *ibid.* **12**, 361, 439, 655, 711, 767 (1941); *Rev. Sci. Inst.* **12**, 125, 177, 525 (1941).

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"American physicists and the war," *Rev. Sci. Inst.* **12**, 46, 114, 283 (1941).

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"Conference on science and world order," *Nature* **148**, 331, 338, 388–392, 424–427, 454–457, 485–489 (1941).

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NOTES AND DISCUSSION

A Neglected Lesson from the Cartesian Diver

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Our Cartesian diver is a grotesque little glass imp with a tail that curls around his legs. At the tip of his tail is the necessary hole by which the water outside communicates with that within. Because the efflux from this hole is almost in a horizontal direction the diver starts his ascent from the bottom with a neat pirouette. This maneuver was noticed and properly understood by the class.

"But," asked a thoughtful student, "why doesn't he spin the other way when you send him down?"

He doesn't. How would you have explained it?

The Training Needed for Work in the Naval Research Laboratory

R. P. BRISCOE
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THE Sound Division of this laboratory is of the opinion that the best training for new men is basic physics and mathematics with some emphasis on wave motion in different mediums, electronics, vacuum tubes and circuits. Aptitude in the use of laboratory equipment and in making measurements is, of course, essential. Special courses in acoustics would be of doubtful immediate value because the work here has always been confidential and the information is not available to the teachers. However, the fundamentals of some of the work are given in Stewart and Lindsay's textbook and other books of a similar character. It seems probable that we could use approximately ten college graduates of the type described by June, 1942.

The same qualifications hold for research workers desired by our Radio Division. As regards the needs for the other divisions of the laboratory, the problem likewise boils down to a demand for training in the fundamental principles of the various branches of science, preferably with a maximum amount of time given to laboratory work.

Defense Training Courses in Acoustics

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ON the basis of our experience with the defense research program, I wish to suggest that courses in acoustics offered under the ESMDT or any similar program should have the following features. The courses should include:

(1) Mechanics of vibration, wave motion and sound

(2) Electro-acoustic devices, such as microphones, loudspeakers, hydrophones and underwater sound transducers of the crystal and magnetostrictive types

(3) Acoustic measurements, including the calibration of electro-acoustic transducers; the measurement of acoustic impedance; experience in the use of sound recorders, cathode-ray oscillographs, vacuum tube amplifiers, oscillators, rectifiers, modulators and so forth.

It is believed that these courses should be of college grade and should be planned for physics majors who have completed general physics and elementary calculus.

There is definitely a shortage of men who have the equivalent of an A.B. degree and a knowledge, both theoretical and experimental, of the subjects listed above. If the work of our defense research laboratory continues to expand as it has done in the past nine months, we should certainly seek the services of men who would stand highest in their classes after completion of these special courses in acoustics.

Training of Optical Workers

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THE established optical industry normally employs in several capacities people who have special knowledge in the field of optics. They can be classified as follows:

I. Research and development
- (*a*) Physicists and chemists
- (*b*) Optical engineers
- (*c*) Instrument designers
- (*d*) Lens designers

II. Production
- (*a*) Inspectors
- (*b*) Factory supervisors
- (*c*) Optical workers, frequently called "lens grinders"

III. Sales

The kind of optical knowledge required by each group is to a considerable extent peculiar to that group.

The most elaborate educational background is required by group I. The successful conduct of problems of pure research in which group I(*a*) might be engaged may involve knowledge of every field of physics and chemistry. The optical engineer, I(*b*), is a physicist—sometimes a chemist—who is generally conversant with the fields of geometrical and physical optics to a degree that can be realized only by adding some years of practical experience to the formal instruction received in college and university courses. He is more specialized in optics than the average physicist and must be more versatile than the instrument designer, I(*c*). The instrument designer must have the same familiarity with *Gaussian optics* that we all have with the multiplication table. He must understand thoroughly the limitations imposed on optical performance by the phenomena of physical optics and must know classical mechanics, as well as something about the practical mechanics of the machine shop. He must know enough about the processes of manufacture of both optical and mechanical parts to avoid asking for impossibilities and must be conscious of the factor of cost. Lens designers, I(*d*), need a very thorough knowledge of geometrical optics with special emphasis on those sections thereof that deal with the subject of aberrations. Efficient lens designing requires a background of considerable experience and depends upon that experience and upon intuition at least

as much as it does upon theoretical considerations; but the theory is, nevertheless, a fundamental necessity.

While it is convenient to classify the staff of an optical laboratory according to the foregoing plan, it does not follow that in actual practice the work is so definitely segregated. The larger the organization, the more likely it is that specialization approaching the aforementioned classification may be found. The smaller the organization, the more versatile must be the individual, until we get down to the one-man staff which must perform the functions of all of the subdivisions of group I and, in addition, assume some of the responsibilities of groups II and even III.

Inspectors, II(*a*), should know the theory of image formation in optical instruments and also how much to expect in the way of image quality. They should be able to determine whether the unsatisfactory performance of an instrument is the result of faulty workmanship or of faulty design.

Factory supervisors, II(*b*), should understand the functions of the various elements in an optical instrument—objectives, eyepieces, collective lenses, prisms of various kinds and so forth. They should know enough about image quality to understand the viewpoint of the inspectors and to be able to exercise independent judgment in such matters when this becomes necessary. Naturally, they must be thoroughly informed on the methods of grinding and polishing glass, of producing geometrically accurate surfaces and of grinding prism angles to close tolerances.

Optical workers, II(*c*), need skills rather than theoretical knowledge.

Salesmen, III, should be able to discuss the performance of instruments with a background of knowledge of the possibilities of instrument performance based on the laws of physical and geometrical optics.

Special intensive courses in optics such as various Government agencies might sponsor in colleges and universities probably would not contemplate training for groups II(*c*) and III.

The principal problem before the country today, insofar as we know it, is production, not design. We know nothing of the optical problems that the National Defense Research Committee may be facing. All we can say is that no design problems have been presented to us that could be advanced appreciably by people who have been given short-term intensive courses in optics, insofar as we can foresee the competence of such individuals in the field of optical instrument design. The amount of optical information required for such work is more extensive than it seems possible to compress into short-term courses, unless the students have previously had considerable general training in optics. That leaves the graduates of such short-term courses with the prospect of finding places for themselves in groups II(*a*) and II(*b*).

The inspection departments of the large optical concerns are constantly obliged to add personnel as production increases and would welcome applications from people who have been trained in short-term optical courses. Furthermore, it would appear that small optical shops that are planning to undertake optical work and that have no optical experts in their employ—with the possible exception of some spectacle lens prescription men—could use with profit some of the graduates of such intensive courses. These individuals would fall into group II and, to some extent, into group I(*b*) as regards the type of activity in which they would engage. Inasmuch as these smaller concerns will probably be working with formulas that are furnished to them, they probably have less need for lens designers than for people with enough theoretical knowledge to understand the functions of the separate elements in an instrument and the effects of departures from perfection in workmanship, who know enough about optical instruments to have an idea as to whether the performance achieved is likely to be acceptable, who know the possible sources of trouble when trouble is encountered, and who have some idea at least about the methods of manufacture of optical elements. We do not know how many of these small companies will engage in optical work or whether they will feel that they need any such assistance. Consequently, we cannot predict the number of people that are likely to be absorbed in this way.

Supplementary remarks by Mr. Carl L. Bausch.—The Bausch & Lomb Optical Company could use a few optically trained men as inspectors at the present time; and I feel sure from my contacts with the Navy Bureau of Ordnance and Army Ordnance Department that they could well use several dozen of such trained people.

In regard to factory supervisors, I think that here, too, an appreciable demand will develop during the next several years. There are undoubtedly a dozen small optical shops in the country that need bolstering up to help carry the war load, and if these shops are put under government pressure, I am sure that a need will arise for some trained people. In our own work we could certainly use a dozen or two supervisors, if they were available. In training optical people for factory supervision, one must remember that knowledge of the job is probably only 25 percent of the requirements. Many other qualifications are necessary, as the readers of this journal well realize.

Shop Work for the Physics Teacher

K. Lark-Horovitz
Purdue University, Lafayette, Indiana

THE teaching of science in the schools is handicapped not only by a lack of coordination within the science department and by the absence of a logical sequence, but also by a notable lack of manual training on the part of the teacher. Most science teachers trained in the usual university or college courses become familiar with the technics of the research laboratory; but these alone are of little value to the teachers in small schools that lack elaborate equipment and that are in need of men and women who are skillful in the use of hand and machine tools and in making emergency repairs.

We think that every teacher training program should include a course in shop technics. Such a course, as we

recommend it, consists of two parts. The use and application of hand and machine tools, elements of glass blowing, the elements of patternmaking and elementary design are taken up in the first half of the course. The practical knowledge so gained is used in the second half, which is intended to make the student-teacher familiar with the use and repair of physical equipment as it occurs in the schoolroom. While the use of elaborate apparatus is an aid to the effective demonstration of many aspects of physical problems, it is essential that the prospective teacher become familiar with the use of improvised equipment which can be duplicated without difficulty by his students. Only in this way can science and observation of experimental detail be made a part of the student's daily routine in the science room. This type of laboratory exercise, which I like to call the "Five and ten laboratory," was a great favorite some 50 years ago. Nowadays the acquaintance with complicated modern devices has developed in the prospective teacher the attitude that physics or chemistry can be taught only by the use of very expensive equipment. Actually, modern industrial developments have made available a large amount of electrical and mechanical equipment which can be easily purchased—or could up until the time of the war—on even a meager budget such as is available in the ordinary school.

This is particularly true if the teacher is acquainted with the use of tools and can make use of the rather good shop facilities available in most secondary schools. Actually, there is very little contact between the science department and the shop. The teaching of science would gain in content as well as method if the science teacher could draw on the shop experiences and observations of the students; his science would be more interesting to the student and would gain in importance. As it is, the students leave the secondary school with the feeling that physics and chemistry have little connection with what they see and do, and that scientific training is of little importance.

Some schools have what is called *related science*, which is taught by the vocational teacher. Courses of this type can be taught by a vocational teacher who is partially reimbursed from federal funds. In this way school systems unable to afford a separate science department can teach the rudiments of physics and mathematics, and this fact is particularly important now in the war effort. We should insist that all students with aptitude for manual handling of tools be encouraged to take *science and shop practice*. The combination of theoretical discussion and the practical application of the conclusion thereof is the foundation of our engineering training. This training should be encouraged at the earliest possible age level, and it should be combined with training in the fundamentals of geometry and algebra.

Scientific training is incomplete without the quantitative formulation of thought and the practical application in the setting up of well-handled experiments. This complete coordination of science, mathematics and the shop is the goal which we must achieve now with the greatest possible speed so as to assure a continuous flow of students for advanced training in science, warfare and industry.

Demonstration of the Oscillatory Discharge of a Condenser

H. E. Hammond
University of Missouri, Columbia, Missouri

It has long been agreed that the rotating-mirror method of demonstrating the oscillatory nature of the discharge of a condenser through an inductive resistance is not particularly suitable for first-year physics classes. *Demonstration experiments in physics*[1] contains a description of a relatively simple circuit, wherein the oscillatory discharge is made evident by a glow on both sectors of a small neon lamp, and the nonoscillating discharge through a high resistance is indicated by a glow on one sector only. Eldridge[2] describes a circuit containing a large condenser and an electromagnet of such magnitude that the frequency of oscillation is low enough to cause *separately* visible, successive flashes on the two sectors of the neon lamp. The writer has been told by Professor Eldridge that this equipment produces only two flashes in general.

Adopting the first of the two circuits mentioned, the writer has built a demonstration panel using a 40-μf condenser and a Thordarson radio choke rated at 12 h and 105 ohms; the resulting frequency is approximately 7.3 cycle/sec. If the condenser is charged to about 200 v, a series of three easily separable flashes is obtained. As calculated from the aforementioned data, the residual voltage after the third discharge is about 70 v, which is too small to cause a fourth flash; but it is easy to show that the condenser is not yet fully discharged. The panel also bears a high resistor of about 50,000 ohms for demonstrating a slow unidirectional discharge, and a 7.5-w clear-bulb tungsten lamp in the charging circuit to show a brief flash as the condenser charges up. Suitable switches are provided. Of course, electrolytic condensers should not be used.

This panel has two superior features: it is portable, and the particular circuit constants used permit *more separable* flashes than the other circuits mentioned. Students seem to grasp quite readily the ideas involved in the demonstration.

[1] Sutton, ed., *Demonstration experiments in physics*, **E-267**, p. 365.
[2] Eldridge, *College physics* (ed. 2), p. 509.

Demonstration Experiments

Julius S. Miller
Dillard University, New Orleans, Louisiana

(1) *A simple demonstration of atmospheric pressure.*—An ordinary rubber "suction" cup, used for supporting hooks from glass windows, provides an excellent demonstration of atmospheric pressure. For a quantitative demonstration, a fairly smooth metal plate with a hook in the center of one side is needed. The suction cup is also equipped with a hook. One hook is attached to a stand, and weights are added to the other hook until separation occurs. Knowing the load and the projected area of the flattened cup, one can then compute the pressure. Since the rubber stretches as the load on it is increased, the edges of the cup are forced inward by the atmospheric pressure; hence the

actual maximum load is less than the computed value. This effect can be diminished by using a metal surface that is slightly rough and yet smooth enough to maintain a vacuum.

(2) ***Enhancing the instructional value of demonstration experiments.***—Many students miss most of the physics and even the essential point of a demonstration experiment. That this is the case may be verified by asking students for statements, in their own words, of the physics involved. To help remedy this pedagogic defect, the writer requires his students to submit written reports on demonstration experiments. The reports are mainly descriptive, contain diagrams and are in the student's own words. The student is urged to place the account in the form that he would use in presenting the topic orally. Copying from textbooks, although it should be discouraged, at least serves to relate the textual material and the experiment. These reports are examined critically, graded and returned. Obvious advantages of this scheme are that it encourages the student to think through the phenomena observed and to report them in his own words. For those students who aspire to classroom teaching, the method should be especially helpful.

SUMMER COURSES, SYMPOSIUMS AND MEETINGS

A.A.P.T.

A regional meeting of the American Association of Physics Teachers will be held at Salt Lake City, Utah, on Tuesday, June 16, during the summer meeting, June 15–20, of the Pacific Division, American Association for the Advancement of Science.

The Association will also meet at the Pennsylvania State College, State College, Pennsylvania, on June 25–27, concurrently with the summer meeting of the American Physical Society. One session will be devoted to a symposium on "College Physics Teaching and the War." Special attention will be given to the question of retraining secondary school teachers of physics to prepare them as instructors in numerous local training centers that are likely to be set up. (See "S.P.E.E. Physics Program.")

Brown University

The program of instruction and research in mechanics and allied branches, which was begun last summer, will be continued during the summer session, June 15 to August 29, as well as during the next academic year. The following courses will be offered this summer:

Introduction to partial differential equations, L. Brillouin; *Geometrical foundations of mechanics*, W. Prager; *Theory of flight*, S. Bergman; *Review of special topics in pure mathematics*, S. Bergman; *Elasticity*, I. S. Sokolnikoff; *Fluid dynamics*, S. Bergman; *Advanced dynamics*, L. Brillouin; *Differential and integral equations of physics*, J. D. Tamarkin and W. Feller; *Electromagnetic waves*, S. A. Schelkunoff; *Advanced elasticity*, I. S. Sokolnikoff; *Plasticity*, W. Prager; *Advanced fluid dynamics*, R. von Mises and S. Bergman; *Research in mechanics and applied mathematics*, W. Prager, I. S. Sokolnikoff and S. Bergman.

Columbia University

The following courses will be offered in the summer session:

s105, Electronics. A laboratory course with supplementary lectures; the experiments include vacuum tube characteristics, oscillators, detectors, sweep circuits, thyratrons, filters, Lecher wire systems and power supply circuits.

s112, Alternating current theory.

s123, Analytical mechanics, statics.

s124, Analytical mechanics, kinetics

ESMDT Summer Programs in Acoustics, Acoustic Engineering and Ultrasonics

To meet the great need for technical personnel for the Army and Navy and for acoustic experts in the various government laboratories, including the Naval Research Laboratory, the Naval Ordinance Laboratory and the special Naval sound laboratories now in operation on both seaboards, four centers for advanced summer instruction in acoustics have been established. The courses are open to advanced undergraduates and graduates in physics and engineering who will be available for employment next fall. Although the announced prerequisites vary slightly, the *minimum* requirements are general college physics and elementary calculus. In addition to the special ESMDT courses in acoustics, regular summer courses in physics and mathematics will be offered concurrently at the four centers, and the student may be permitted to select some of them to round out his program. The programs vary in length, depending upon the institution.

At *Brown University*, June 15 to August 29, the courses are under the supervision of R. B. Lindsay, who will also give the lectures; the summer program of advanced instruction and research in mechanics may be combined with the acoustics program in special cases. At the *Case School of Applied Science*, June 15 to August 8, where J. J. Nassau is in charge, additional advanced courses in electrical theory and mathematics will be available. J. Kaplan will be in charge at the *University of California at Los Angeles*, June 15 to September 5, where the work will be given by N. A. Watson, R. W. Leonard and additional men in the fields of sound and electronics, drawn from the Navy Sound and Radio Laboratory at Point Loma. At the *University of Iowa*, June 15 to July 10, the program will consist of conferences and library work, two lectures each day on basic theory and applications, and a daily laboratory on acoustic fundamentals and the use of electric circuits in the production, use and measurement of acoustic energy; the lectures for the first three weeks will be given by G. W. Stewart and James Jacob, and for the last week, by H. F. Olson, Research Director, RCA Manufacturing Company.

Massachusetts Institute of Technology

The tenth summer conference on *Spectroscopy and its applications*, to be sponsored this year jointly by the Institute and the Optical Society of America, will be held on July 20, 21 and 22. A symposium on fluorescence and phosphorescence is planned in connection with the conference. Reservations must be made in advance with Professor G. R. Harrison.

The usual courses in spectroscopy will *not* be given at the Institute this summer.

Stanford University

F. Bloch will give an intermediate course on *Modern physics* and an advanced course on *The electromagnetic field*. Facilities for research and informal work will also be available.

S.P.E.E. Physics Program

An all-day symposium of the Society, the American Association of Physics Teachers and the American Physical Society, on "College Physics Teaching and the War," will be held at the Pennsylvania State College on June 25:

Research in physics for the war program. K. T. Compton, *Massachusetts Institute of Technology*.

Need for combined training in basic engineering and advanced physics. Ross Gunn, *Naval Research Laboratory*.

Education in physics for the war program. H. L. Dodge, *University of Oklahoma*.

The special war training program in physics at Brown University. R. B. Lindsay, *Brown University*.

Elementary physics in the Pennsylvania State College ESMDT program. M. W. White, *Pennsylvania State College*.

A dinner meeting at Columbia University, New York, on June 27, will be devoted to a symposium as follows:

Symposium: Which systems of units should be emphasized in physics courses for engineering students? (1) *The mks system of units*, R. N. Varney, *Washington University;* (2) *Thermodynamics and mechanical engineering*, J. I. Yellott, *Illinois Institute of Technology;* (3) *Mechanics*, Seibert Fairman, *Purdue University;* (4) *Electrical engineering and engineering in general*, R. E. Doherty, *Carnegie Institute of Technology;* (5) *Physics*, R. B. Lindsay, *Brown University*.

State University of Iowa

An intensive course in *Acoustics and acoustic engineering*, June 15 to July 10, will be offered jointly by the Department of Physics and the College of Engineering, under the ESMDT program. In addition to conferences and library work, there will be two lectures each day, on basic theory and applications, and a daily laboratory which will deal not only with acoustic fundamentals but more extensively with the use of electric circuits in the production, use and measurement of acoustic energy. The minimum prerequisites are one year of college physics and elementary calculus. The lectures for the first three weeks will be given by Dr. G. W. Stewart, assisted by Dr. James Jacob, both of the University of Iowa. The 12 lectures of the last week will be given by Dr. H. F. Olson, Research Director, RCA Manufacturing Company. Advance applications for enrolment must be sent to Dean F. M. Dawson, College of Engineering.

University of Chicago

During the summer quarter, June 22–September 11, a full program of undergraduate and graduate courses is offered. In addition, a *Spectroscopic conference* will be held June 22–25, emphasizing pure science aspects of spectroscopy in its relations to astronomy, chemistry and physics. The conference will consist of a series of symposiums in these fields, so arranged as to bring together, in any two successive days, combinations of topics of interest to various individuals or groups.

The tentative program is as follows:

Monday morning, W. E. Williams, *California Institute of Technology*, and W. F. Meggers, *Washington* (interference methods and wavelength standards); H. G. Beutler, *Chicago* (concave grating theory); *Monday afternoon*, A. M. McKellar, *British Columbia*, P. Swings, *Yerkes Observatory*, and N. T. Bobrovnikoff, *Perkins Observatory* (cometary spectra); *Monday evening*, F. L. Whipple, *Harvard Observatory* and C. T. Elvey, *MacDonald and Yerkes Observatories* (earth's atmosphere); *Tuesday morning*, W. F. Meggers (spectra of the rare earths); K. W. Meissner, *Purdue*, J. Mack, *Madison*, and R. A. Fisher, *Northwestern; Tuesday afternoon*, O. Struve, *Yerkes Observatory*, R. Wildt, *Princeton* (constitution of the planets); *Wednesday morning*, E. F. Barker, *Ann Arbor*, R. S. Mulliken, *Chicago*, and S. Mrozowski, *Chicago* (triatomic molecular spectra and structure); *Wednesday afternoon*, H. Sponer, *Duke University*, W. H. Rodebush, *Urbana*, and A. L. Sklar, *Catholic University* (spectra of organic molecules, with theoretical computations); *Wednesday evening*, L. G. Brooker, *Kodak Research Laboratories*, and A. L. Sklar (spectra of dyes); *Thursday morning*, Emma P. Carr, and Lucy W. Pickett, *Mt. Holyoke*, R. S. Mulliken and C. A. Rieke, *Chicago and Massachusetts Institute of Technology*, M. Goeppert-Mayer, *Columbia* (spectra of organic molecules, and theoretical computations); *Thursday afternoon*, S. E. Sheppard, *Kodak Research Laboratories*, E. Rabinowitch, *Massachusetts Institute of Technology*, and S. Freed, *Chicago* (spectra of dye polymers and of complex ions); *Thursday evening*, G. N. Lewis, *University of California* (absorption and fluorescence spectra of dyes frozen in rigid mediums).

University of Michigan

Owing to the present emergency, the annual symposium in theoretical physics will not be held this summer. However, a regular program of courses will be offered as a third term, and a group of graduate courses, in an eight-weeks session.

University of Pittsburgh

An expanded program of summer courses will be offered. In addition, there will be special courses in x-rays and spectroscopy of particular interest to industrialists.

It is better to know a few things and to have the right use of them than to know many things which you cannot use at all.—Seneca

RECENT MEETINGS

CHICAGO CHAPTER

AT the February meeting of the Chicago chapter of the American Association of Physics Teachers the principal speaker was Professor R. F. Paton, of the University of Illinois, who discussed the place of physics in the engineering curriculum. The ideas expressed by Professor Paton may upset, to a certain extent, the feelings of some "purists" among physicists who have faith in the more or less standardized presentation of the subject both with respect to the length of time devoted to each topic and the sequence in which it is presented. In his discussion the speaker emphasized the need for a more functional course—especially, when taught to engineering students—and the need for a departure from the standardized course which, after all, is the result, not of a planned development, but of a synthesis of the needs of a general education and the physicist's conception of what is most important in present-day physics.

From his experience with engineering extension courses offered in industrial regions, Professor Paton concludes that the general physics course should give increased emphasis to the mechanical properties of materials, such as inertia, elasticity and viscosity, and to problems of the transfer and transformation of heat. Treating these topics in greater detail would leave less time for sound, light and modern physics, which might well be given in a third semester and only to smaller, more specialized classes. Professor Paton prefers to introduce the topic of mechanical oscillations and wave motion in the latter part of the work on electricity, where a review of certain mechanical concepts is quite appropriate. This arrangement would lead to a better balance of work for the two essential semesters and would bring the study of wave motion into the course at a time when the students are frequently better prepared to handle the mathematics.

At the same meeting Dr. Ph. A. Constantinides and Dr. L. I. Bockstahler reported on the Princeton meeting of the Association and Dr. Harold R. Voorhees, on the "Colloquium on Electronics" held at the University of Iowa.—PHILLIP A. CONSTANTINIDES, *Chapter President.*

OREGON CHAPTER

THE thirtieth meeting of the Oregon chapter of the American Association of Physics Teachers was held at Linfield College on February 14, 1942. President W. V. Norris presided. Eighteen persons were in attendance.

The following papers were presented:

A study of long-time attendance at the University of Oregon. W. V. NORRIS, *University of Oregon.*

Improvements of laboratory experiments. E. H. COLLINS, *University of Oregon.*

Student likes and dislikes. E. H. COLLINS, *University of Oregon.*

Recent latent image theories. J. C. GARMAN, *Oregon State College.*

Applications of ultra-high frequency. E. A. YUNKER, *Oregon State College.*

As a result of a general discussion on the profession of physics, the chapter voted to recommend that an investigation be made as to the desirability of having either the Association or the American Institute of Physics establish the general requirements of one or more physics curriculums—for teachers, technical physicists and so forth—leading to the bachelor's degree. It was not suggested that curriculums be laid down along hard and fast lines but rather that minimum requirements for physics, mathematics and chemistry be specified, that the desirable spread in other fields be indicated and that language requirements, if any, be named. The discussion brought forth comparisons of similar actions taken by the American Medical Association, the Society for the Promotion of Engineering Education, the American Chemical Society and other professional groups. Objections to such procedure on the part of accrediting organizations were mentioned. The chapter felt that action along this line on the part of one of our national organizations will help to stabilize physics as a profession and that this is an opportune time for such action.—W. WENIGER, *Secretary pro tem.*

KENTUCKY CHAPTER

The Kentucky Association of Physics Teachers met jointly with the Kentucky Academy of Science at the University of Kentucky, Lexington, on the morning of April 11. Four papers were heard:

Three great mathematicians and physicists. C. G. LATIMER, *University of Kentucky.*

Measurement of relative intensities of soft x-rays. CHARLES L. OWENS, *University of Kentucky.*

Experiments in constructing diffraction gratings. R. A. LORING AND E. B. MONTGOMERY, *University of Louisville.*

Effects of high rotational speeds and heat treatment on the magnetization of iron. FRED J. LEWIS, *University of Kentucky.*

On the afternoon of April 17 a meeting was held at the Henry Clay Hotel, Louisville, in conjunction with the Kentucky Education Association. The following papers were heard:

High school mathematics and physics. ELIZABETH MAYO, *University of Louisville.*

A unified science program for high schools. C. V. KETRON, *Frankfort High School.*

An experiment on classroom motion pictures. CARL ADAMS AND R. A. LORING, *University of Louisville.*

Gyroscopes—a demonstration lecture. JARVIS TODD, *University of Kentucky.*

The present officers of the chapter are L. A. Pardue, University of Kentucky, President, and W. C. Wineland, Morehead State Teachers College, Secretary.—W. C. WINELAND, *Secretary.*

ILLINOIS CHAPTER

The Illinois State Association of College Physics Teachers, newly affiliated with the national Association as a regional chapter, met on May 8 and 9, at the time of the annual meeting of the Illinois State Academy of Science. R. F. Paton, representative of the chapter on the executive committee of the national organization, reported on the Princeton meeting and also discussed defense programs and

review courses for school physics teachers which have been proposed by the University of Illinois. A report was heard on the work of the A.A.P.T. committee on the teaching of physics in the secondary schools. During the luncheon period, members of the State normal school faculties reported on their progress in cooperating with this committee. The chapter also met jointly with the Academy of Science in two sessions devoted to addresses by P. G. Kruger, on "The Construction, Operation and Uses of the Cyclotron," and by D. W. Kerst, on "The Operation and Uses of the Betatron."

R. W. Lefler is president of the chapter this year.—CHAS. T. KNIPP, *Secretary*.

NEW ENGLAND SECTION

The eighteenth regular meeting of the New England Section of the American Physical Society was held at Smith College, Northampton, Massachusetts, on October 11, 1941. Four invited papers were presented:

The teaching and research programs of the department of physics at Smith College. GLADYS A. ANSLOW, *Smith College*.

The native protein, a problem for physics. DOROTHY WRINCH, Visiting Lecturer, *Smith, Mount Holyoke* and *Amherst Colleges*.

Stroboscopic photographs used in the teaching of mechanics. FRANCIS W. SEARS, *Massachusetts Institute of Technology*.

A defense training course in radio technics. WILLIS RAYTON, *Dartmouth College*.

The nineteenth regular meeting of the Section was held at Worcester Polytechnic Institute, Worcester, Massachusetts, on March 28, 1942. The invited papers were as follows:

Physical methods of dosage determination in x-ray therapy. EDITH H. QUIMBY, *Memorial Hospital, New York City*.

The opportunities for the college physics department in the present war. JOSEPH C. BOYCE, *Massachusetts Institute of Technology*.

Physics at Worcester Polytechnic Institute. MORTON MASIUS *Worcester Polytechnic Institute*.

The relation of mathematics training to physics training. ALBERT A. BENNETT, *Brown University*.

Every new science teacher a prospective defense training teacher. K. LARK-HOROVITZ, *Purdue University*.

The last two papers were the basis of a symposium on "The science teachers' training program."

A total of 16 ten-minute papers were contributed at the two meetings. The abstracts for three of these appear below. Abstracts for the remaining papers will be found in *The Physical Review* **61**, 99–100 (1942) and **61**, June 1 and 15 issue (1942).

Demonstration experiments with tuning forks. ERIC ROGERS, *St. Paul's School*.—(1) *Primitive demonstration of "wave-form" of fork's motion*. A small mirror on the fork reflects sunlight, or light from a lantern, to a wall. The demonstrator holds the shank of the fork and twists it with his fingers. The mirror is attached with a strip of mica or celluloid to increase its motion. (2) *Interference*. Two 256-cycle/sec forks giving very slow beats are placed close together on boxes and sounded. When the loudness is a *minimum*, one fork is stopped. The audience hears more sound from the remaining fork than from both together. (3) *Resonance*. A small mirror on a steel fork reflects light to a wall. The fork is excited by an electromagnet run by a variable-frequency oscillator. When the fork vibrates, the spot of light on the wall becomes a band, the size of which is a measure of the fork's response. The oscillator frequency is varied over a wide range, and the band size gives a response-curve showing resonance peaks.

Adapt the instruction to the student. RUSSELL S. BARTLETT, *Newark College of Engineering*.—In the course of a nation-wide survey of some aspects of engineering education, the writer was impressed by the large number of failures in mathematics and physics among engineering students. The conclusion is inescapable that the subjects, as taught, are too extensive or too difficult for many of the students. Either the students should be excluded from the courses or provision should be made for instruction more compatible with their abilities and preparation. Yet the solution does not lie in lowered standards throughout; rather there is need for instruction graded according to individual abilities, since some are able to take all that is offered at present, and ask for more. Though opinion is far from unanimous, there is evidence, subjective and objective, that graded sectioning and graded instruction make it possible for the gifted student to study as widely and deeply as he may wish, while retaining the opportunity for those less gifted to acquire a mastery of those minimum essentials which are required for further study and success in engineering. Exploration of the possibilities of this method with control groups receiving nonspecialized treatment may help to establish our teaching technics on a sounder basis.

The physics of driving an automobile. C. R. FOUNTAIN, *Amherst College*.—Charts or lantern slides showing the results of experiments and the mathematical formulas which govern the handling of an automobile under various road conditions, coefficients of friction, sharpness of curves, speeds in passing and so forth, make it easy to explain how to avoid accidents in driving an automobile.

The officers for 1942 are: P. M. MORSE, *Chairman;* GLADYS A. ANSLOW, *Vice Chairman;* ALICE H. ARMSTRONG, *Secretary-Treasurer;* H. MARGENAU AND A. P. R. WADLUND, *Program Committee*.—ALICE H. ARMSTRONG, *Secretary-Treasurer*.

I hold every man a debtor to his profession; from the which as men of course do seek to receive countenance and profit, so ought they of duty to endeavor themselves, by way of amends, to be a help and an ornament thereunto.—BACON, Preface to *Maxims of the Law*.

RECENT PUBLICATIONS AND TEACHING AIDS

INTERMEDIATE AND ADVANCED PHYSICS

Five hundred problems in optics. FRED H. PERRIN. Ed. 2. 37 p., lithoprinted, paper cover, 21×27 cm. *The author* (475 Sagamore Drive, Rochester, N. Y.), $1.20 plus postage. The supply of the 1933 edition having become exhausted, the author has now reissued this useful collection of problems, but with only a few corrections of errors, so that copies of both editions can be used interchangeably. Covering such broad topics as first-order image theory, ray tracing, radiation, photography, ophthalmic optics, instrument design and microscopy, the problems are especially designed to supplement Hardy and Perrin's *The principles of optics*. However, sufficient material is included to make the collection extremely useful in connection with other textbooks as well.

Electricity and magnetism. Rev. Ed. NORMAN E. GILBERT, Professor of Physics, Dartmouth College. 602 p., 394 fig., 15×22 cm. *Macmillan*, $4.50. Although the general outline of the 1932 edition is retained, the author has extensively revised numerous portions of the text in the light of the experiences of various teachers with the book. The chapter on electron tubes and part of the chapter on electrical communications have been entirely rewritten in collaboration with WILLIS M. RAYTON. Among the new additions are a chapter on the theory of dielectrics and electric induction, sections on magnetic theory, moving electrons and electron optics, and an extension of the chapter on units and dimensions to include discussion of newly adopted and proposed systems of units. Most of the problems are new.

Introduction to modern physics. Ed. 3. F. K. RICHTMYER, Late Professor of Physics, and E. H. KENNARD, Professor of Physics, Cornell University. 736 p., 234 fig., 15×23 cm. *McGraw-Hill*, $5. In order that this notable textbook may remain true to its title and thus take into account the theoretical and experimental advances of the last decade, PROFESSOR KENNARD has faced the difficult task of revising the text; and this he has done in an able manner and so thoroughly that only a minor part of it stands substantially as in the edition of 1934. The historical introduction has been abbreviated and is now followed by a single rewritten chapter on the topics in electromagnetism most needed for the subsequent discussion. Between the chapters on the photoelectric effect and on the origin of the quantum theory is inserted a short chapter on relativity. Next comes a single chapter on the essential ideas concerning the nuclear atom, spectral series and atomic quantum states. A descriptive chapter on wave mechanics is then followed by a single chapter on the theory of the periodic table and on optical spectroscopy. The chapter on x-rays has been thoroughly revised in collaboration with L. G. PARRATT. The book closes with the chapter on the nucleus, considerably extended, and a new chapter on cosmic rays.

Principles of mechanics. J. L. SYNGE, Professor of Applied Mathematics, AND B. A. GRIFFITH, Lecturer in Applied Mathematics, University of Toronto. 526 p., 162 fig., 15×23 cm. *McGraw-Hill*, $4.50. Developed from lectures given by the authors to second and third year honor students at the University of Toronto, this modern and thoughtfully planned textbook for a one-year course in theoretical mechanics covers the usual range of theory and applications, up to and including introductions to the Lagrange equations and to restricted relativity. Use is made of elementary differential equations throughout the book, and of vectors and the complex variable wherever they provide the most efficient tools. Believing that "the art of teaching consists largely in isolating difficulties and overcoming them one by one, without losing sight of the main problem while attending to the details," the authors have divided their treatment into two self-contained parts, the one dealing mainly with plane mechanics, the other, with mechanics in space. Thus, from the beginning, the student deals with fundamentals but without being confused by too many details; and he has access to many of the most interesting results of mechanics, which are in plane theory, without having to wait until he has mastered the more elaborate technic required for three dimensions.

An introduction to physical statistics. ROBERT BRUCE LINDSAY, Hazard Professor of Physics, Brown University. 315 p., many fig., 15×23 cm. *Wiley*, $3.75. Treatises on statistical mechanics and on the detailed applications of statistics to the properties of matter are generally intended for the specialist and hence fail to provide an introduction to the methods of statistical physics that will be most useful to the beginner in graduate work who has only a preliminary knowledge of theoretical physics. The present book supplies such an introduction, in the form of a relatively thorough survey of the various ways in which statistical reasoning has been used in physics from the classical applications up through the contemporary quantum mechanics. Both methodological aspects and specific applications are stressed, and the similarities as well as the differences of the various statistical methods are emphasized. The chapter titles are: Dynamical and statistical theories; Elementary probability and statistics; Review of thermodynamics; Classical Maxwell-Boltzmann statistics; Kinetic theory of gases; Classical statistical mechanics; Statistical mechanics by the method of Darwin and Fowler; Fundamentals of quantum mechanics; Specific heats; Quantum statistical theory of electric and thermal properties of metals; Emission of electrons from surfaces. Numerous problems are provided.

APPLIED PHYSICS

Electrical illumination. JOHN O. KRAEHENBUEHL, Professor of Electrical Engineering, University of Illinois. 448 p., many illustrations and tables, 15×23 cm. *Wiley*, $3.75. This textbook differs from other books on illuminating

engineering and photometry in that it has been prepared specifically for the use of sophomore students of architecture, architectural engineering and electrical engineering. Among the main topics covered are the objective and subjective specifications of illumination, color and shadow, distribution curves and the point-by-point method of determining illumination, light sources and control, general illumination design, floodlighting, novelty lighting and wiring. Only simple algebra and trigonometry are used in the treatment. Many problems and literature references are included.

Dynamic meteorology. BERNHARD HAURITZ, Associate Professor of Meteorology, Massachusetts Institute of Technology. 375 p., 89 fig., 15×23 cm. *McGraw-Hill*, $4. Based on lecture courses given during the past six years as part of the meteorological program offered by the University of Toronto in cooperation with the Meteorological Service of Canada, this textbook deals with the investigations and results that have arisen from the recent applications of thermodynamics and hydrodynamics to the study of the atmosphere and its motions. The emphasis is on applications to practical weather forecasting and to research. Recent advances which have led to air mass analysis, frontal and isentropic analysis and the wave theory of cyclones are included. A knowledge of the underlying physics, but not of meteorology, is assumed. Calculus is employed, but the mathematical technic has been kept as simple as possible. Lists of problems and of specific references to the literature are supplied.

MISCELLANEOUS

Civilian pilot training manual. Ed. 2. 341 p., 132 fig., 20×27 cm. *Superintendent of Documents* (Washington, D. C.), paper cover, 65 cts. Although designed primarily for the use of students taking the elementary ground and flight courses and the secondary flight course of the highly successful Civilian Pilot Training Program, this manual should be equally useful to all student pilots as a guide to safe flying. The alterations made in the present edition were the work of D. L. WEBSTER.

Aircraft instruments. GEORGE ELLIS IRVIN, President, Irvin-Aircraft Instrument Schools. 516 p., 545 fig., many tables, 15×23 cm. *McGraw-Hill*, $5. Prepared especially for use as a textbook in aircraft schools and technical high schools and as a practical reference manual for aircraft operators and manufacturers, this book provides a simple but comprehensive and up-to-date treatment of the functions, principles of design and operation, installation, maintenance and repair of modern aircraft instruments. All types are covered, including meteorological, engine, navigation and flight instruments.

The chemical formulary, Vol. 5. H. BENNETT, Editor-in-Chief. 694 p., 22×14 cm. *Chemical Publishing Co.*, $6. The present volume of this well-known series contains thousands of the latest tested formulas and recipes dealing with adhesives, beverages, cosmetics, drugs, emulsions, farm and garden specialties, foods, inks, leather, skins, furs, lubricants, oils, fats, construction materials, metals and metal treatment, paints, paper, photography, polishes, pyrotechnics, explosives, rubber, resins, plastics, waxes, soaps, cleaners, textiles, fibers and so forth. An introductory chapter of directions and advice has been provided for those who lack experience in the art of chemical compounding. A good index and a detailed directory of commercial sources of chemicals and supplies are included. All of the formulas in the five volumes of this series are different.

LANTERN SLIDES

Virtual objects in lenses and mirrors. L. M. ALEXANDER (319 Joselin Ave., Cincinnati, O.), set of 15 slides, $9; selected slides, 85 cts. Six of these slides contain the diagrams, Fig. 3 excepted, of Professor Alexander's article on "Virtual objects in mirrors and thin lenses" [Am. J. Phys. **10**, 110 (1942)].

PAMPHLETS

Weights and measures. Letter circulars LC 449, LC 681 and LC 682. Mimeographed. *National Bureau of Standards* (Washington, D. C.), gratis. These circulars, entitled *Length, mass and time* (8 p.), *Units and systems of weights and measures* (12 p.) and *General tables of weights and measures* (15 p.), were prepared especially to answer the many inquiries made by school students and others on these subjects.

Bell Telephone System technical monographs. *Bell Telephone Laboratories* (463 West St., New York), gratis.

B-1319, *Contribution of statistics to the science of engineering*, by W. A. SHEWHART. 28 p., 3 fig. A survey of the potential contributions of statistics to engineering as a national asset.

B-1324, *Television—the scanning process*, by P. MERTZ. 24 p., 12 fig. The general nature of the television signal; relation of the received image to the scanning process.

B-1327, *Stereophonic sound-film system*. 96 p., 63 fig. Seven papers on the system demonstrated before the Acoustical Society of America, May 1, 1941.

The mobilization of science in national defense. F. B. JEWETT. 16 p. *Bell Telephone Laboratories* (463 West St., New York), gratis. A sketch of the setup of organized civilian research and development created for the war emergency, by the President of the National Academy of Science.

I count myself happy in the search after truth—it is really pitiful that there are so few that seek truth.—*Galileo*

DIGEST OF PERIODICAL LITERATURE

OBJECTIVE TESTS

Objective test items of the recognition type that test reasoning and minimize guessing. T. A. ASHFORD, W. A. SHANNER, *J. Chem. Ed.* **19**, 86–89 (1942). Test items of the recognition type (multiple-choice, true-false) are open to the criticism that they test memory and not reasoning, or that they can be answered by guessing. A method of meeting both these criticisms is to use paired test items, one of which requires the selection of a prediction from pertinent data, or a numerical result, while the other asks for the basis of the prediction, or the physical units for the answer. The chance of successful guessing is reduced by giving credit only when *both* items are answered correctly. It is necessary in such a test that both items together test a single idea. Tests of this kind given at the University of Chicago indicate their value and furnish a statistical justification for the method of scoring. Such tests can be adapted to machine scoring.—J. D. E.

EFFECTIVENESS OF THE ESMDT PROGRAM

Are the EDT-ESMDT programs expediting defense? H. H. ARMSBY, *J. Eng. Ed.* **32**, 5–9 (1942). Industrial and governmental executives have been asked, both by the OPM and by colleges and universities participating in the ESMDT program, to give their opinions as to the effectiveness of this program in expediting defense. The overall picture presented by more than 1000 letters received in response to these requests seems to be as follows: (1) the program is in general performing the service for which it was created, but its efficiency can be improved in some respects in a few institutions; (2) the program should undoubtedly be continued during the emergency, but its size will need to be determined by some means other than consultation with industrialists, few of whom are in a position to have any valid data for estimating future needs on a quantitative basis; (3) many employers are still not thoroughly informed as to the program and its objectives, which indicates a need for closer coordination with industry and with other training programs; (4) courses should always be organized to meet known or anticipated war needs, not to meet the desires of an educational institution or of a group of prospective trainees; (5) in organizing courses, industrialists should be consulted as to subject matter, course outline and qualifications of trainees; (6) quite frequently men from industry will be better teachers for ESMDT courses than will regular faculty members, but they may require rather careful educational supervision to insure optimum results; (7) some of the regular faculty members could increase their value as ESMDT teachers by closer contacts with the industries for which their courses prepare men; (8) care should be exercised in selecting students, in respect to their educational background, practical experience, general fitness for the work of the course and ultimate employability in defense industries; (9) in general, employers should be kept informed of the progress being made by their employees in ESMDT classes, unless the employee specifically requests that this not be done; (10) it must always be borne in mind that this is an *intensive training* program rather than an *educational* one, that its primary objective is to expedite defense production and that all other benefits, real and valuable as they may be, are secondary.—D. R.

A PROBLEM ON THE DOPPLER EFFECT

A Problem. W. E. BLEICK, *Am. Math. Mo.* **49**, 195 (1942). A bomb which is equipped with a whistle of constant frequency falls *freely* from rest at an initial angular elevation θ, as seen by an observer at a fixed point on the ground, and hits the ground at a distance L from the observer. (a) Find the angular elevation of the bomb at the moment when the apparent pitch is highest. (b) Show that, if the initial elevation θ is small, the apparent pitch is maximum when the bomb has lost one-third of its initial altitude.—H. E. M.

APPARATUS AND DEMONSTRATIONS

Measurement of surface tension and density by a modified capillary rise method. E. TYLER, *Sch. Sci. Rev.* **23**, 159–165 (1942). A glass tube is bent into the form of a letter J. To the short arm is attached a piece of capillary tube by means of a short section of rubber tubing. The capillary tube dips into a glass vessel containing the liquid to be studied and the long arm of the J-tube dips into water in a vessel whose height may be altered, so as to control the pressure above the liquid in the capillary. The pressure is measured by an open manometer attached to the horizontal tube as near to the capillary as possible. The point of a needle is brought to the free surface of the liquid to serve as a reference mark. The capillary, manometer and needle point are projected on a screen, and measurements of distance are made on the enlarged image. Calibration is effected by projecting, with the same optical system, the image of a glass scale placed at the point occupied by the capillary. The radius of the capillary is obtained from measurements on the image of a thread of mercury inserted into it.

Allowing for the volume of the liquid above the bottom of the meniscus and assuming zero angle of contact of the liquid with the tube wall, we obtain for the effective elevation, $h+(\frac{1}{3}r)=(2\sigma/r\rho g)-(\rho_1h_1/\rho)$, to a first approximation; here h is the height of the liquid in the capillary, ρ is the density of the liquid and σ is its coefficient of surface tension; h_1 is the difference in levels in the manometer, ρ_1 is the density of the manometer liquid and r is the radius of the capillary. A plot of $h+(\frac{1}{3}r)$ as ordinate against h_1 as abscissa yields a straight line of slope ρ_1/ρ. The value of σ may be calculated from the intercept on either of the axes. If tubes of different radii are used, one obtains a family of straight lines, all of the same slope. If h_1 is regarded as constant for a given set of tubes, the equation is linear in $h+(\frac{1}{3}r)$ and $1/r$. Thus, by choosing several values of h_1 and plotting corresponding values of $h+(\frac{1}{3}r)$ and $1/r$, a new family of straight lines is obtained, all of slope $2\sigma/\rho g$, from which a better value of σ is obtainable.—J. D. E.

CHECK LIST OF PERIODICAL LITERATURE

Ten questions that students of chemistry will be asking—and their answers. *J. Chem. Ed.* **19**, 90 (1942). These questions relating to selective service will be asked by students of physics also. Students in training for scientific work are urged, as a patriotic duty, to seek deferment, in the event they are drafted.

Dr. Franklin as the English saw him. C. READ, *J. Frank. Inst.* **233**, 105–123 (1942).

Forces and atoms—the world of the physicist. K. K. DARROW, *Sci. Mo.* **54**, 197–210 (1942).

Science and the problem of human values. J. M. FLETCHER, *Sci. Mo.* **54**, 259–265 (1942). Should science in the present era continue to deal "not with values but with facts"?

The impact of science on contemporary civilization. R. B. LINDSAY, *Sigma Xi Quart.* **30**, 51–65 (1942).

The physics of art. F. I. G. RAWLINS, *J. Sci. Inst.* **19**, 17–22 (1942). A good survey and bibliography of the physical technics in the critical evaluation of articles of *virtu*.

Biological basis for ethics. R. W. GERARD, *Phil. of Sci.* **9**, 92–120 (1942). Under the action of applied science, "men over larger areas are squeezed into functional relations, communities become more integrated and more extensive. We are rapidly entering the inevitable phase of a world state as a single human epiorganism." Through painful readjustment, as is the case in all evolutionary processes, "the social conscience is gaining strength. . . . Human altruism is increasing. The great problem for the future is to direct the selfish drives which remain into nondestructive outlets."

Philosophy and science. R. B. WINN, *Phil. of Sci.* **9**, 1–18 (1942). A characterization of philosophy is set forth which makes it very like science. "It is not a graveyard of speculative systems . . . , a museum of ingenious theories . . . , but a forum of life where the main activity consists in an eager search of understanding and in an intelligent building of beliefs."

Meteorites and the age of the solar system. W. J. ARROL, R. B. JACOBI AND F. A. PANETH, *Nature* **149**, 235–238 (1942). A bibliography is included.

Science and international politics. SIR R. GREGORY, *Nature* **149**, 261–263 (1942).

Teaching of science. ANON., *Nature* **149**, 161–162 (1942). Report of an English conference on the problems of providing needed technicians now and in reconstruction, and on reducing the present distinction between cultural and technical education.

Hypotheses non fingo. A. E. BELL, *Nature* **149**, 238–240 (1942). A comparison of Newton's use of hypotheses with their present use.

Galileo Galilei, 1564–1642. H. C. PLUMMER, *Nature* **149**, 206–208 (1942). A critical appraisal of his place in history and his concept of the sacredness of scientific truth.

Hygroscopic properties of clothing in relation to human heat loss. J. H. NELBACH AND L. P. HERRINGTON, *Science* **95**, 387–388 (1942).

Symposium on optics in national defense. *J. Opt. Soc. Am.* **32**, 123–138 (1942). Papers by Ballard, Kingslake and Driscoll on navigation and fire control, aerial photography and crime detection.

Sun and ionosphere. ANON., *J. Inst. Elec. Eng.* **88**, 400–413 (1941).

The civic morals of science. C. C. WILLIAMS, *J. Eng. Ed.* **32**, 504–510 (1942). "The warp of scientific realism is no less essential than the woof of humanistic idealism in the fabric of civic morals for an advancing organized society."

Engineering aptitudes: their definition, measurement and use. C. V. MANN, *J. Eng. Ed.* **32**, 673–686 (1942). A description of the work done in an extensive W.P.A. project at the Missouri School of Mines, 1938–1941.

Sir William Bragg, 1862–1942. W. F. G. SWANN, *Sci. Mo.* **54**, 380–382 (1942).

The nature of cosmic rays and the constitution of matter. R. W. LADENBURG, *Sci. Mo.* **54**, 391–396 (1942).

Facts and philosophies. J. A. GENGERELLI, *Sci. Mo.* **54**, 431–440 (1942). The author, a psychologist, incidentally makes some pertinent criticisms of current physics teaching.

Preparation of science teachers to contribute to general education. S. R. POWERS, *Sch. Sci. and Math.* **42**, 315–324 (1942). A digest of the report of the subcommittee on teacher education of the National Committee on Science Teaching.

Industrial and military explosives. R. W. CAIRNS, *J. Chem. Ed.* **19**, 109–115 (1942).

Dust explosions. J. B. FICKLEN, *J. Chem. Ed.* **19**, 131–134 (1942).

Modern abrasives. H. C. COOPER, *J. Chem. Ed.* **19**, 122–127 (1942).

Priority Assistance in Obtaining Critical Materials

APPLICATIONS of colleges and schools for priority assistance in obtaining critical materials, such as shop tools and equipment, and steel and copper for new buildings, will henceforth be handled by a recently created "Schools Section" of the Governmental Requirements Branch, Division of Purchases, War Production Board. Mr. George Fink, Purchasing Agent of Cornell University, is chief of the section.